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# A Guide to

# CATHODE RAY PATTERNS

Merwyn Bly

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*A Guide to*

# CATHODE RAY PATTERNS

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# *A Guide to* Cathode Ray Patterns

*by*


Clayton

MERWYN BLY

ASSOCIATE ENGINEER (RADIO)

NAVY DEPARTMENT



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# FOREWORD

This book attempts to present under one cover a " sketch-and-caption " summary of cathode ray pattern types encountered in the usual course of laboratory and test bench work. Its format has been kept as nearly like a pictorial reference chart as practicable. For detailed theory and analysis the reader is referred to sources cited in the Reading List as well as to the many other excellent works available.

With some exceptions, practically all the patterns appearing in this guide may also be found in many other books; in fact, most of them are as old as the oscilloscope itself. However, the writer (and others, it is hoped) has felt a definite need for a correlated " minimum-text " presentation in quick and convenient reference form. It is also felt that, in addition to some new methods and material, certain ambiguities in presentation, often encountered, have been avoided here.

Patterns produced for this book were developed with conventional amplifiers and oscillators and viewed on a small oscilloscope using a standard circuit.

The value of graphic and mathematical analysis is in no way underestimated, and a section on simple graphic analysis is included. It is to the 'scope operator who would rather check the chart than plot the points, however, that this little guide is dedicated.

MERWYN BLY

*October, 1942*



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## GENERAL

**The Plates.** References to " vertical " or " horizontal " plates designate the plates actually producing the respective *deflection* and are not intended to designate their actual physical orientation within the oscilloscope.

Input to vertical deflecting plates.

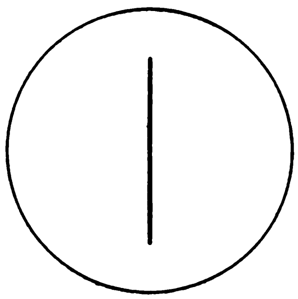
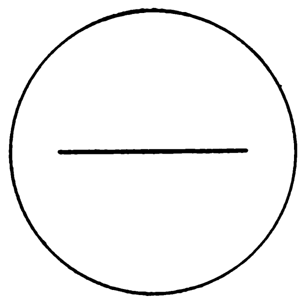


Fig. 1



Input to horizontal deflecting plates.

Fig. 2

**The Sketches.** It is felt that the sketches in this guide are sufficiently accurate for most applications. However, the operator should realize that a few portray very specific conditions as developed and will not have general application. Most of the others will hold good with variations up to the point where it is no longer possible to recognize their similarity to the sketch patterns.

**The Conditions.** The " conditions " in each instance should be carefully noted. In many cases, altering any one condition will materially alter the appearance of the resultant pattern.

**Pattern Notes.** The circles with dotted axes (Sketch Notes) appearing at the end of each section are intended to afford the operator a means of recording patterns of especial interest. It is thought that the opportunity afforded to sketch them in at the time, under the proper classification, will be of value for ready reference later.

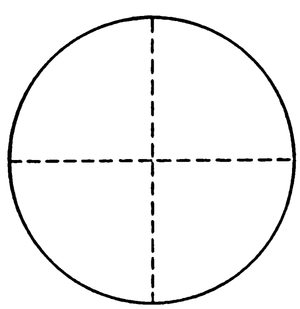


Fig. 3



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## PHASE DETERMINATION

Angle of tilt is predicated on the assumption that zero phase difference produces a " line " running from upper right to lower left, as in Fig. 4. If the pattern for zero phase difference is not already known, the operator should tie free plates together, apply voltage, and check. If " reversed," like Fig. 5, all other patterns will be reversed accordingly, except 90/270°, which is a circle. Direction of the tilt for the series makes no difference in interpretation of the patterns so long as the operator is aware of it before beginning.

**I. Conditions.** Identical frequencies and equal amplitudes (pure wave forms) applied to both horizontal and vertical plates.

*a.* To obtain equal amplitudes, match horizontal and vertical deflection voltage traces first separately. That is with a ruler, set the line *a–b* equal to line *c–d* in Fig. 6 and Fig. 7.

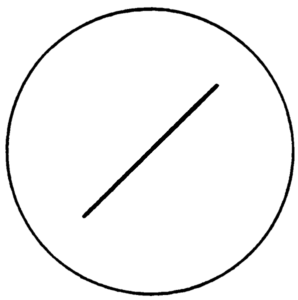

Fig. 4

0/360° pattern as developed for the sketches as they appear in this guide.

0/360° pattern with reverse tilt, occurring when hook-up of scope plates is different from that producing Fig. 4.

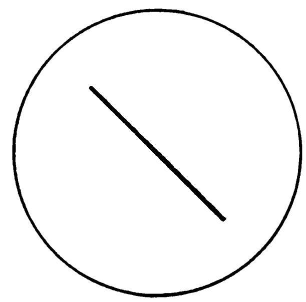

Fig. 5

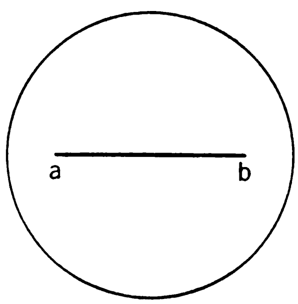


Fig. 6

For equal amplitude, adjust so that line *a–b* in Fig. 6 is equal to line *c–d* in Fig. 7.

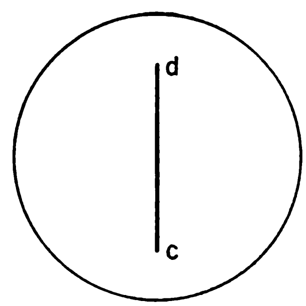


Fig. 7

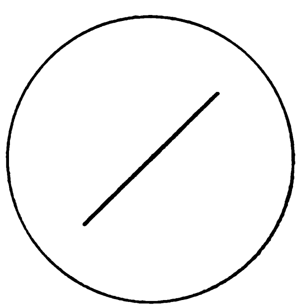

Fig. 8
0/360°

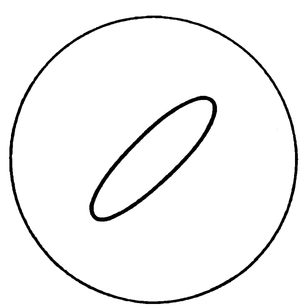

Fig. 9
30/330°

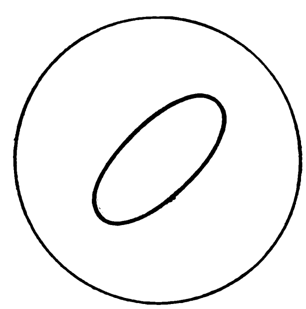

Fig. 10
45/315°

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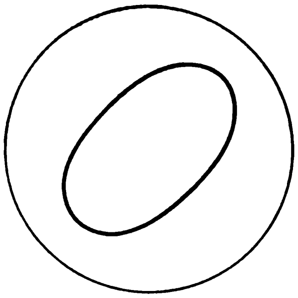

Fig. 11
60/300°

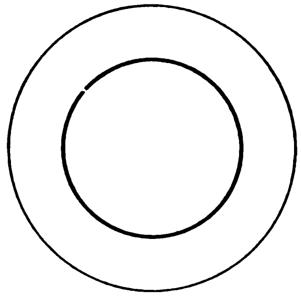

Fig. 12
90/270°

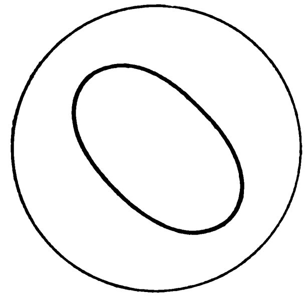

Fig. 13
120/240°

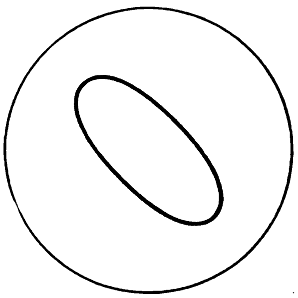

Fig. 14
135/225°

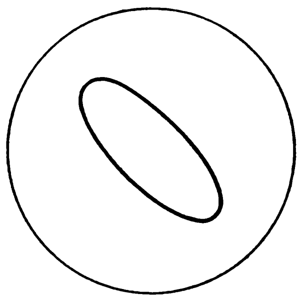

Fig. 15
150/210°

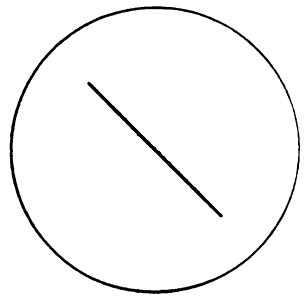

Fig. 16
180/180°

**II. Conditions.** Identical frequencies but unequal amplitudes (pure wave forms) applied to horizontal and vertical plates.

*a.* Note that eccentricity of ellipse changes and major axis turns, depending on the comparative amplitude difference between voltages applied to vertical and horizontal plates; also, that any ellipse whose major axis is either truly horizontal or vertical depicts 90/270 phase difference, irrespective of the eccentricity of the ellipse.

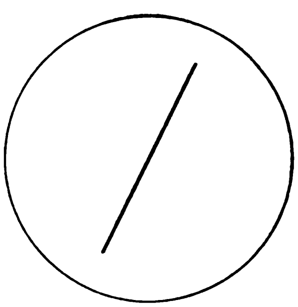

Fig. 17
0/360°

Vertical larger. Axis has turned. Compare with Fig. 8.

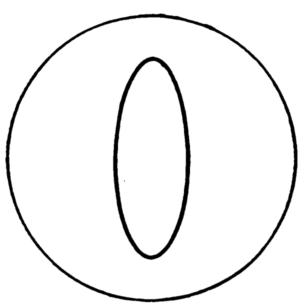

Fig. 18
90/270°

Vertical larger. Circle is now ellipse. Compare with Fig. 12.

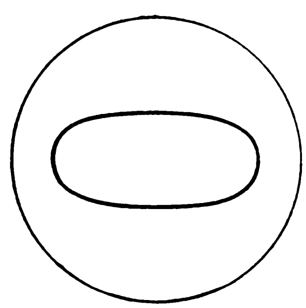

Fig. 19
90/270°

Horizontal larger. Circle also changed to ellipse. Compare with Fig. 12.

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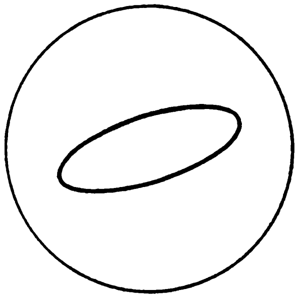
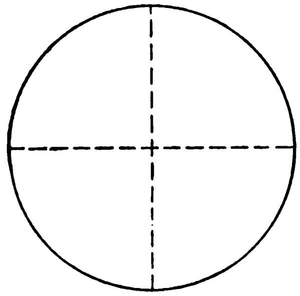
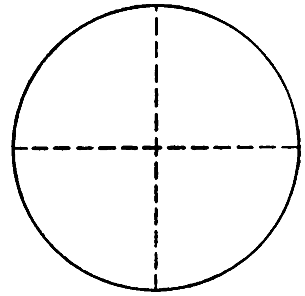


FIG. 20
45/315°

Horizontal larger. Axis turned. Ellipse narrower. Compare with Fig. 10.



Sketch Note



Sketch Note

**III. Conditions.** Identical frequencies and equal amplitudes but pure sine wave applied to horizontal plates and distorted wave applied to vertical plates. The phase difference indicated is that between fundamentals. Sketches show only a few of the countless possible variations, but they should be of assistance in interpreting general types.

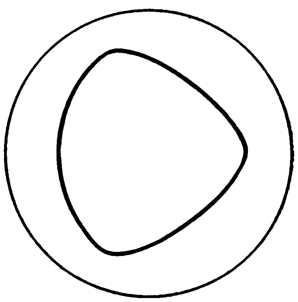


FIG. 21
90/270°

Impure wave has high second harmonic content.

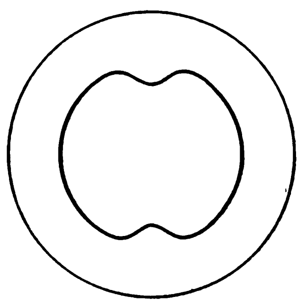


FIG. 22
90/270°

Impure wave has high third harmonic content.

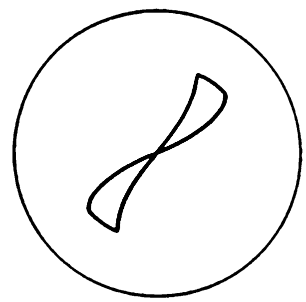


FIG. 23
0/360°

Impure wave has both second and third harmonic content.

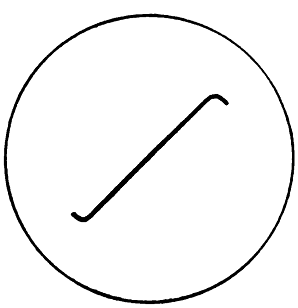


FIG. 24
0/360°

Impure wave is from overloaded Class A amplifier (both peaks flattened).

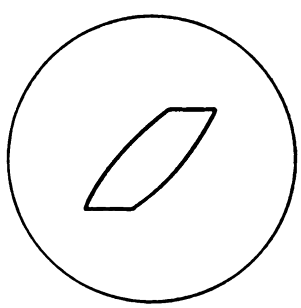


FIG. 25
30/330°

Impure wave from same source as Fig. 24. The overbias is extremely severe.

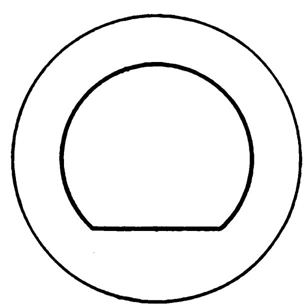


FIG. 26
90/270°

Impure wave is from somewhat overloaded Class A (only one peak flattened).

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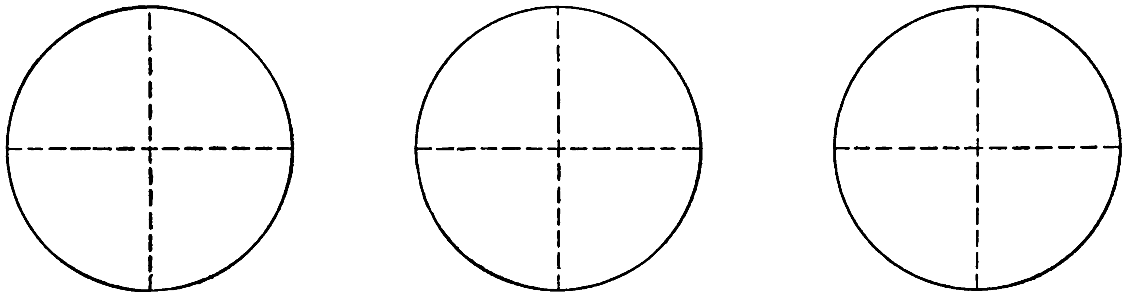

Sketch Note

Sketch Note

Sketch Note

**IV. Phase-Splitting Circuit.** Capable of producing shifts from about 15° to 170°. With good components, reasonably constant voltage output is obtained over the whole range indicated.

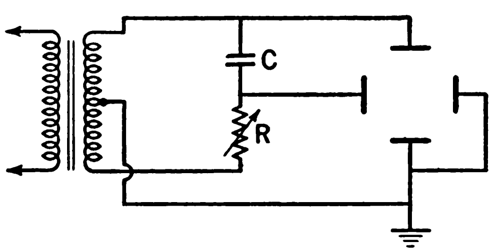


FIG. 27

When $X_c$ equals $\frac{1}{2}R$ for the input frequency, the most favorable operating conditions are usually realized.

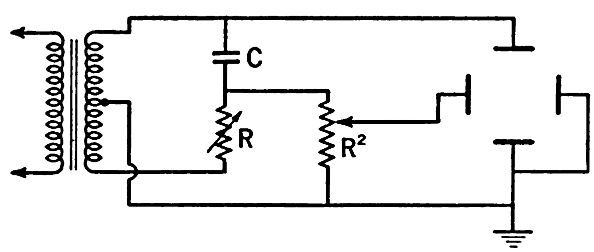


FIG. 28

Here the circuit of Fig. 27 has been modified to include control $R^2$ to adjust the relative amplitude of vertical and horizontal deflection voltages if desired.

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## FREQUENCY DETERMINATION

### Lissajous Figures (Completed-Loop Type)

Lissajous patterns are the resultant of a-c voltages on both sets of plates. All may be used for frequency determination, but the completed-loop type are superior to others for the purpose.

Frequency ratio may easily be determined by points of tangency to horizontal and vertical lines, either drawn or imagined. Points of tangency at the top or bottom of the figure represent the effect of vertical deflection, and points of tangency at the sides represent that of the horizontal deflection.

Note that in Fig. 29 there are four points of tangency at the top due to the vertical and one point at the side due to the horizontal deflection. Thus the frequency of the vertical signal is four times that of the horizontal; and, conversely, the horizontal is one fourth that of the vertical input signal frequency. Thus it can be understood that a pattern can be either 4 : 1 or 1 : 4, depending upon which set of plates is used as the reference standard.

If the patterns " stand on end," as in Fig. 30, then the frequency of the vertical signal is one fourth that of the horizontal, and, conversely, the horizontal is four times that of the vertical. With this in mind, it is apparent that the operator can determine by inspection whether the standard reference signal is the higher or the lower frequency.

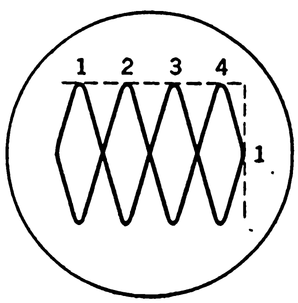


Fig. 29

If a known signal of 60 c/s were applied to the vertical deflecting plates in both Fig. 29 and Fig. 30, the frequency of the unknown signal would be 15 c/s in Fig. 29 and 240 c/s in Fig. 30.

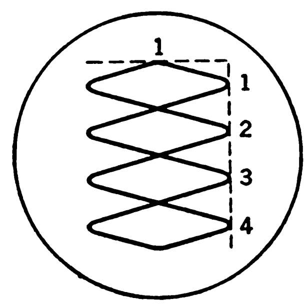


Fig. 30

**I. Conditions.** Signals of sine form to horizontal and vertical plates. Integral ratios. Phase relation such as to uncover loops (for explanation, see III). Note that any pattern configuration would be identical, whether it appeared longitudinally or " on end," and that the ratio is expressed with the largest number here, first, merely for convenience. Interpretation of the ratio depends on the reference standard as explained for Fig. 29 and Fig. 30.

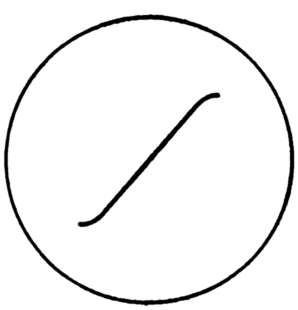

Fig. 31
Ratio 1:1

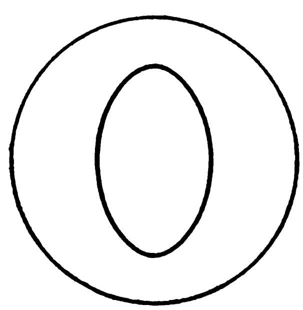

Fig. 32
Ratio 1:1

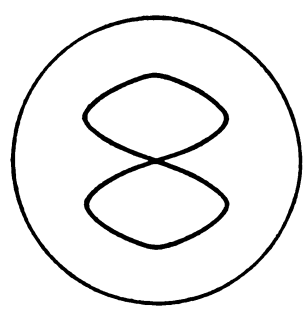

Fig. 33
Ratio 2:1

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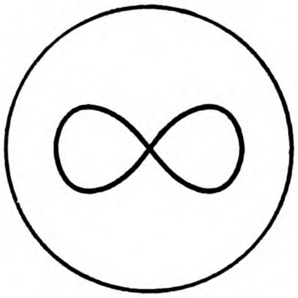


FIG. 34
Ratio 2:1

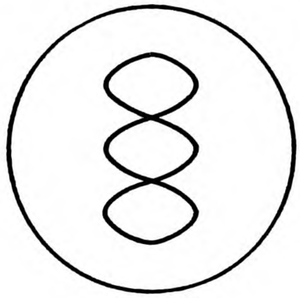


FIG. 35
Ratio 3:1

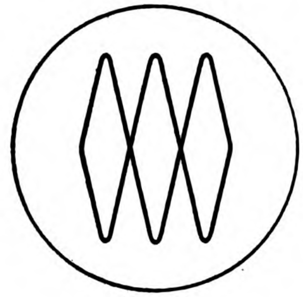


FIG. 36
Ratio 3:1

*a.* Note that phase and amplitude relation of the sine-wave inputs to the vertical and horizontal plates may change the proportion and shape of the loops but that the number of the loops remains constant for each respective frequency ratio.

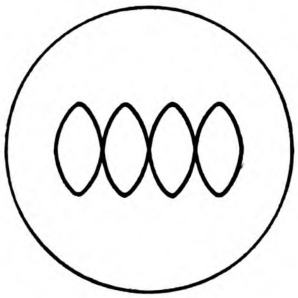


FIG. 37
Ratio 4:1

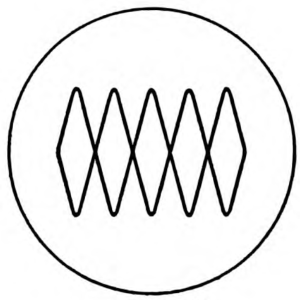


FIG. 38
Ratio 5:1

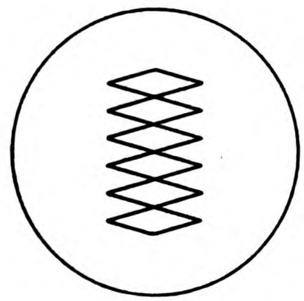


FIG. 39
Ratio 6:1

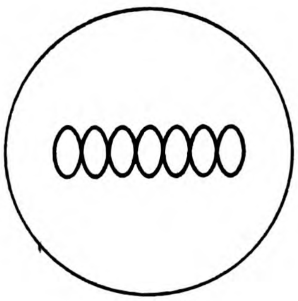


FIG. 40
Ratio 7:1

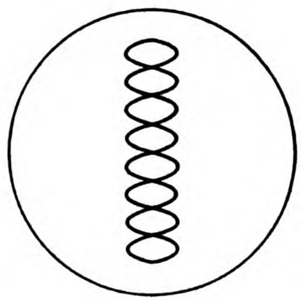


FIG. 41
Ratio 8:1

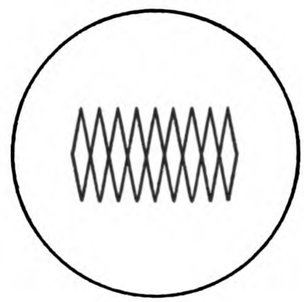


FIG. 42
Ratio 9:1

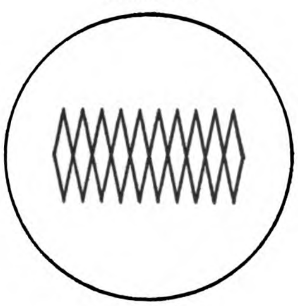
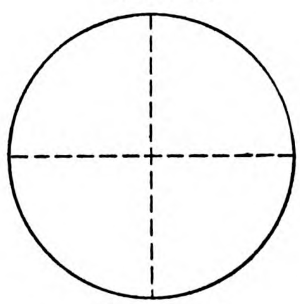
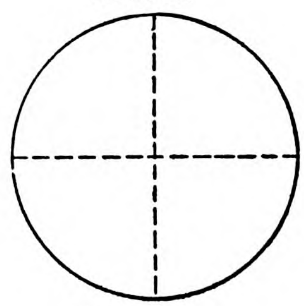


FIG. 43
Ratio 10:1



Sketch Note



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**II. Conditions.** Same as in I, but this group depicts some typical patterns in which the ratio is fractional instead of integral. This type is more difficult to stop on the screen. Considerable care should be exercised to prevent errors of interpretation.

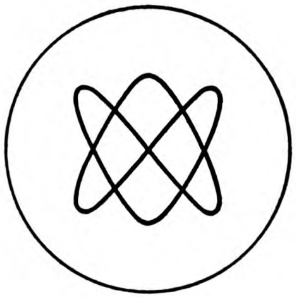


FIG. 44
Ratio 3:2

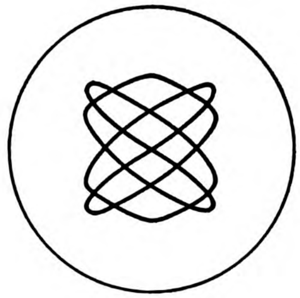


FIG. 45
Ratio 4:3

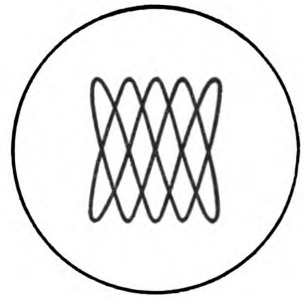


FIG. 46
Ratio 5:2

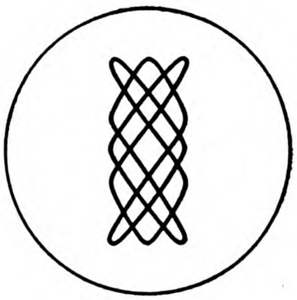


FIG. 47
Ratio 5:3

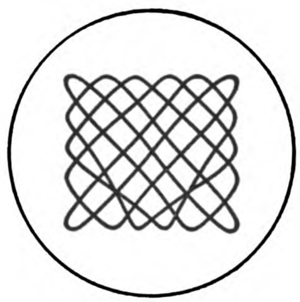


FIG. 48
Ratio 6:5

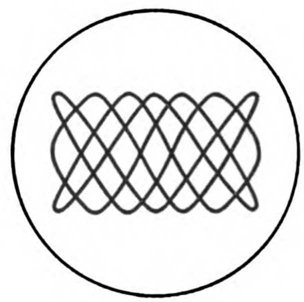


FIG. 49
Ratio 7:3

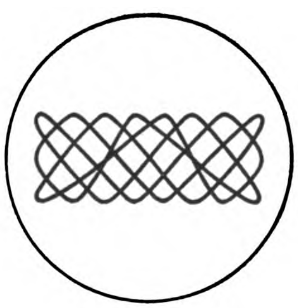


FIG. 50
Ratio 8:3

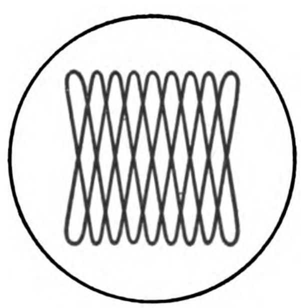
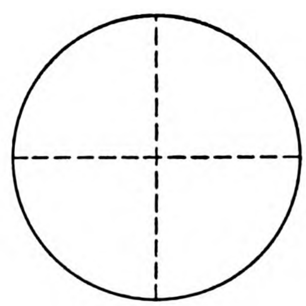


FIG. 51
Ratio 9:2



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**III. Conditions.** Same as I and II, except that a few representative covered-loop patterns are illustrated. Where the phase difference is 0° or 180°, or nearly so, several of the pattern loops are likely to be covered up, i.e., superimposed upon each other. The operator should allow the pattern to drift a bit before stopping it entirely, to make sure that all the loops are exposed.

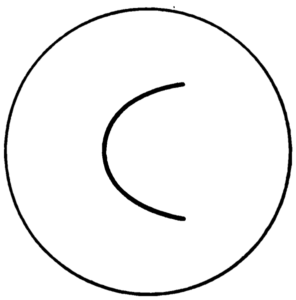

FIG. 52
Ratio 2:1
Loops covered.

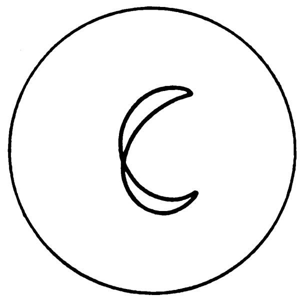

FIG. 53
Ratio 2:1
Loops partly exposed.

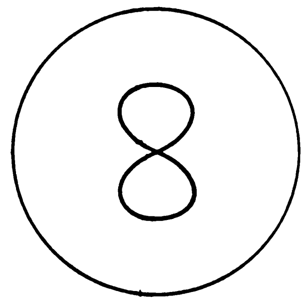

FIG. 54
Ratio 2:1
Loops fully exposed.

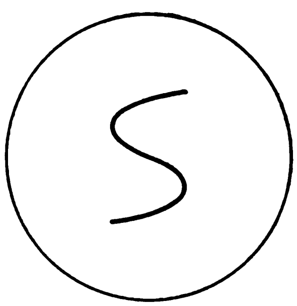

FIG. 55
Ratio 3:1
Loops covered.

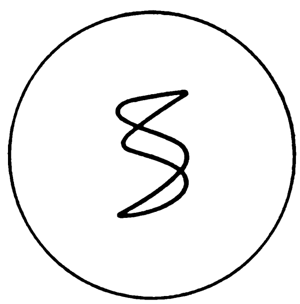

FIG. 56
Ratio 3:1
Loops partly covered.

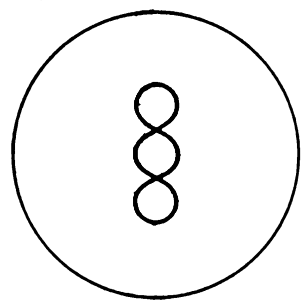

FIG. 57
Ratio 3:1
Loops fully exposed.

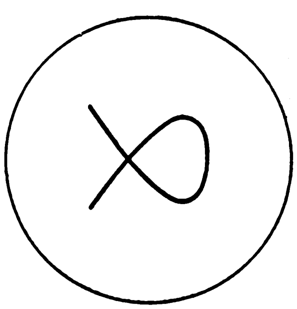

FIG. 58
Ratio 3:2
Loops covered.

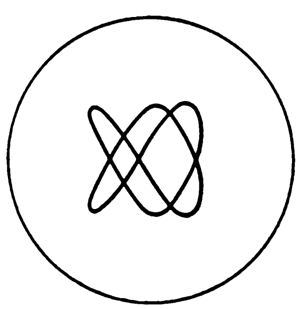

FIG. 59
Ratio 3:2
Loops partly covered.

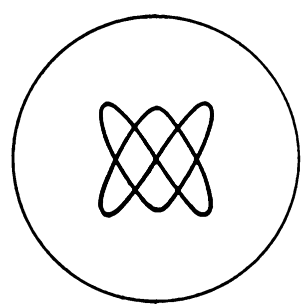

FIG. 60
Ratio 3:2
Loops fully exposed.

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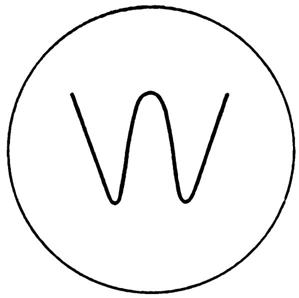


FIG. 61
Ratio 4:1
Loops covered.

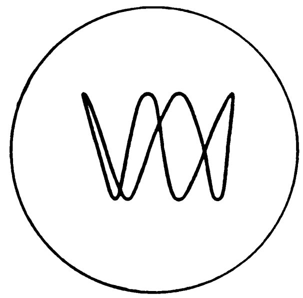


FIG. 62
Ratio 4:1
Loops partly exposed.

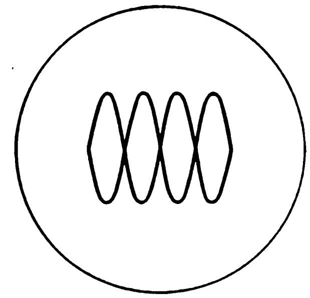


FIG. 63
Ratio 4:1
Loops fully exposed.

**IV. Conditions.** Same as I, II, and III, but one wave impure. It can be noted from Figs. 64, 65, and 66 that, in the simpler ratios, frequency ratio is readily apparent even though the patterns are somewhat distorted. As the patterns grow more complex it is usually impossible to interpret them if the amount of distortion is appreciable. Distorted integral ratios are commonly easier to interpret than fractional ratios.

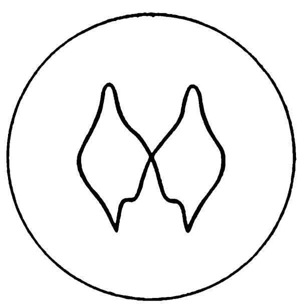


FIG. 64
Ratio 2:1

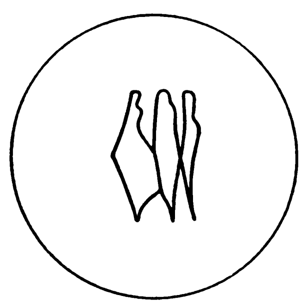


FIG. 65
Ratio 3:1

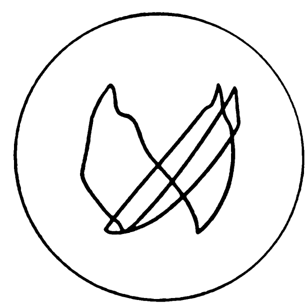
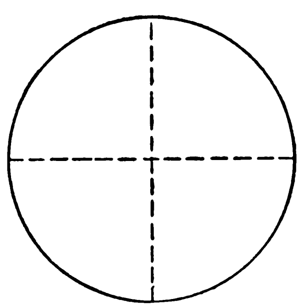
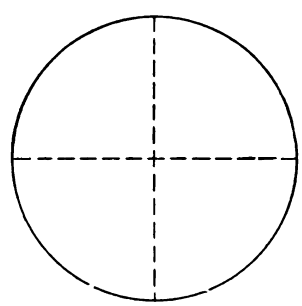


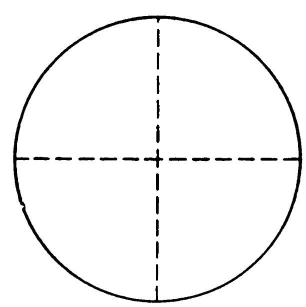
FIG. 66
Ratio 3:2



Sketch Note



Sketch Note



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**V. Conditions.** Sine-wave voltage to both sets of plates but applied across a phase-splitting circuit to separate " front " and " back," thus displacing the two portions on a circle, or an ellipse. Ordinarily employed at 10 : 1 or higher ratios. The practical value of such patterns is somewhat in question as it is usually much simpler to alter the frequency of the known oscillator. However, to complete the record, three examples are given. In the single line (Fig. 67 and Fig. 68) the ratio is the number of loops to one; in the double line (Fig. 69) the ratio is the number of loops to the number of intersecting circumferences (two, in this case).

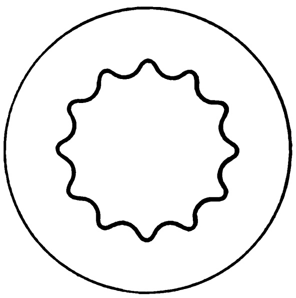


FIG. 67
Ratio 12:1

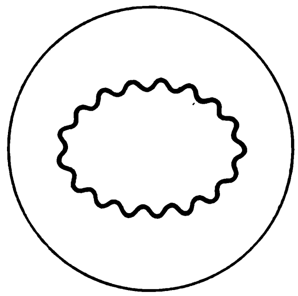


FIG. 68
Ratio 17:1

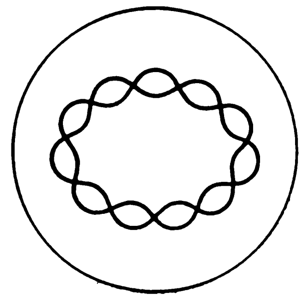
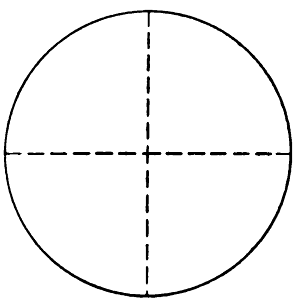
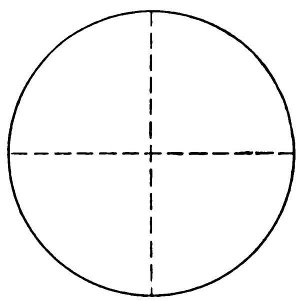
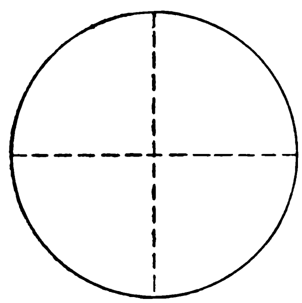


FIG. 69
Ratio 11:2


Sketch Note


Sketch Note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## FREQUENCY DETERMINATION

### Lissajous Figures (Uncompleted-Loop Type)

A linear-sweep oscillator and a source of sine-wave input are assumed. Patterns will differ in horizontal and vertical amplitude according to the comparative voltages appearing at the plates, but their outline form will approximate very closely the reference sketches given.

Reference sketches were developed with the sine-wave input to the vertical plates and the internal 'scope sweep applied to the horizontal plates. The sine-wave input will be referred to as the " signal." Ratios are given as sweep to signal, but obviously the reverse is equally correct. For example, in Fig. 70, if signal input is 60 c/s and the sweep is 12 c/s, then the sweep is 1/5 signal, or signal is 5 times sweep.

These patterns are convenient for calibrating a sweep and some other special uses, but in general this uncompleted-loop type pattern is much inferior to the completed-loop type for frequency determination.

**I. Conditions.** Sine wave (signal) applied to vertical plates, linear sweep applied to horizontal plates.

*a.* The asterisk (*) indicates that either pattern may occur and both are correct.

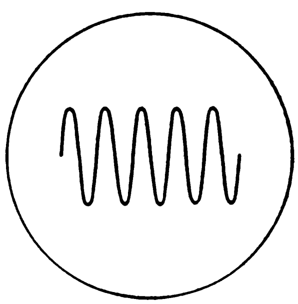

FIG. 70
Sweep is 1/5 signal.

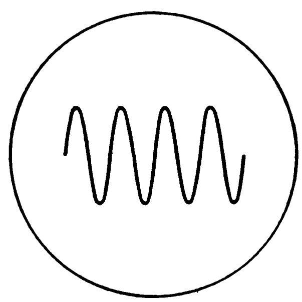

FIG. 71
Sweep is 1/4 signal.

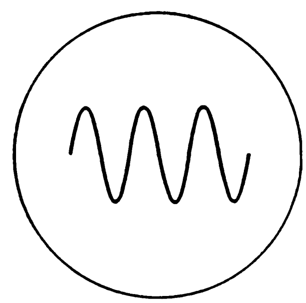

FIG. 72
Sweep is 1/3 signal.

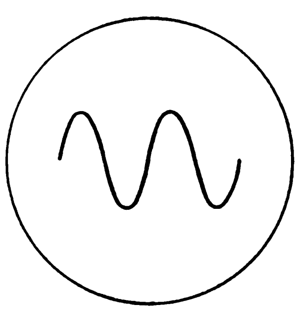

FIG. 73
Sweep is 1/2 signal.

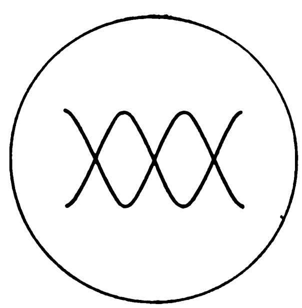

FIG. 74
Sweep is 2/3 signal.

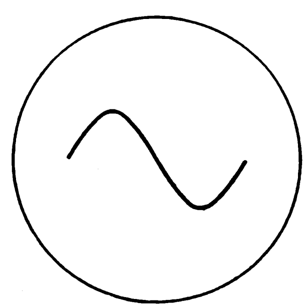

FIG. 75
Sweep is equal signal.

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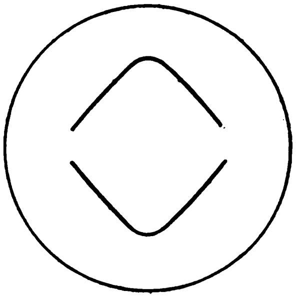


*Fig. 76
Sweep is 2 times signal.

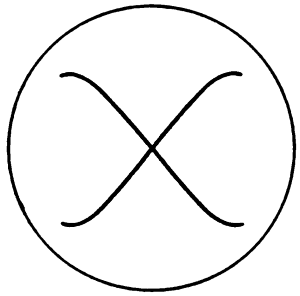


*Fig. 77
Sweep is 2 times signal.

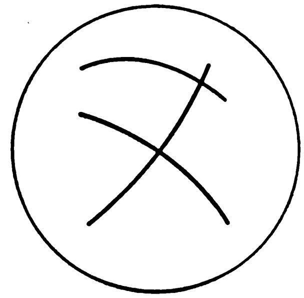


Fig. 78
Sweep is 3 times signal.

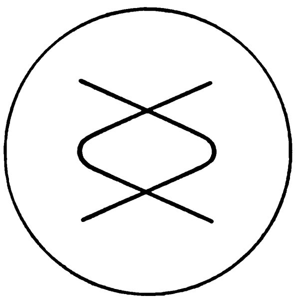


*Fig. 79
Sweep is 4 times signal.

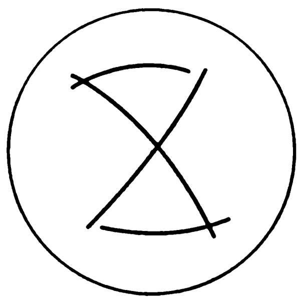


*Fig. 80
Sweep is 4 times signal.

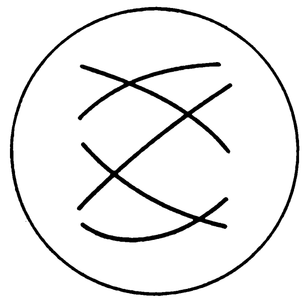
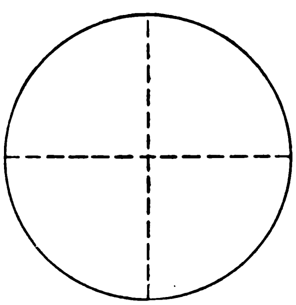
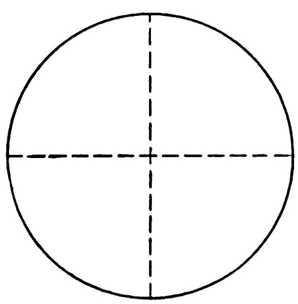


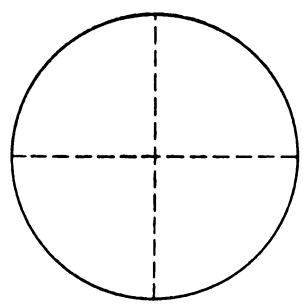
Fig. 81
Sweep is 5 times signal.



Sketch Note



Sketch Note



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## MODULATION PATTERNS

(Trapezoidal Type)

The trapezoidal pattern is rather limited in the range of its possible indications. Nevertheless, for routine tests it is much simpler to develop and use and less liable to errors of interpretation than the wave envelope pattern. Sketches cover a number of typical conditions, but by no means all the possible conditions or combinations of them. Except for Fig. 92, sketches in this section are for plate modulation.

**I. Conditions.** Modulated r-f signal voltage applied to vertical plates and modulator (audio) voltage to horizontal plates.

*a.* Percentage modulation is equal to $\frac{E_{max} - E_{min}}{E_{max} + E_{min}} \times 100$ (Fig. 83). Any convenient unit of measurement may be used.

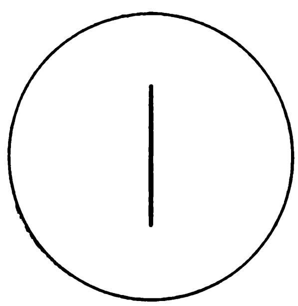

FIG. 82

Unmodulated carrier.

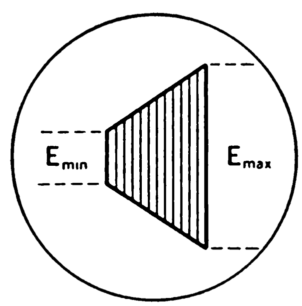


FIG. 83

Approximately 60% modulated.

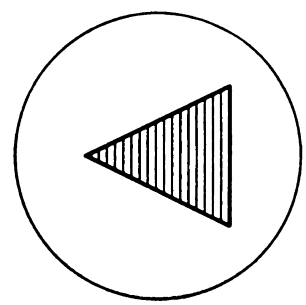

FIG. 84

100% modulated. No distortion. Ideal pattern.

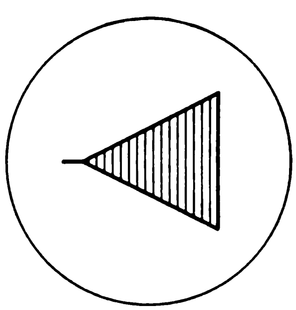

FIG. 85

Overmodulation of a transmitter capable of undistorted 100% modulation.

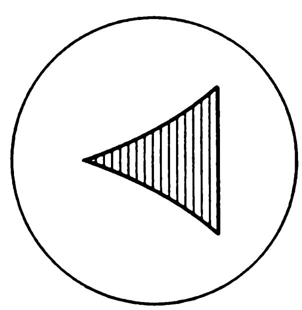

FIG. 86

Regeneration in Class C stage, too much bias, improper neutralization.

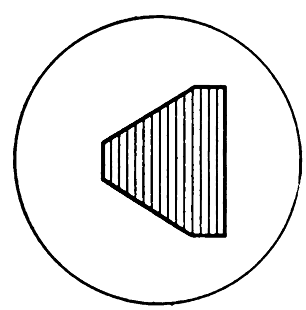

FIG. 87

Insufficient r-f grid drive to modulated amplifier or lack of sufficient filament emission.

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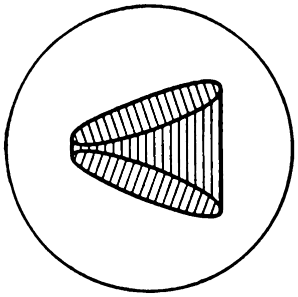


FIG. 88

No distortion, but phase shift. Audio voltage not taken directly from output of modulator.

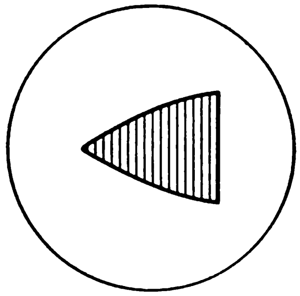


FIG. 89

Class B modulator on a common power supply with modulated amplifier; voltage drop on audio peaks at low audio frequencies when output filter condenser is low value.

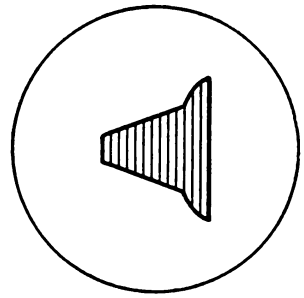


FIG. 90

Screen-grid final. Plate modulated; but screen very little. Screen by-pass too large.

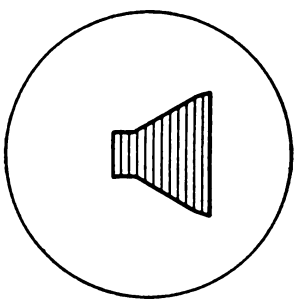


FIG. 91

Class B modulator which is not properly matched to the Class C load.

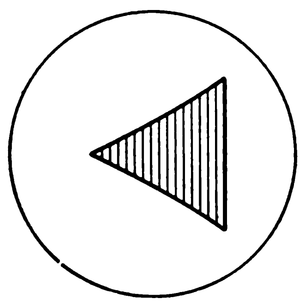
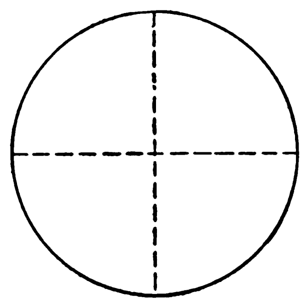
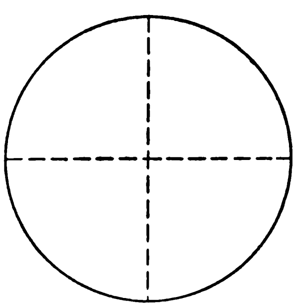


FIG. 92

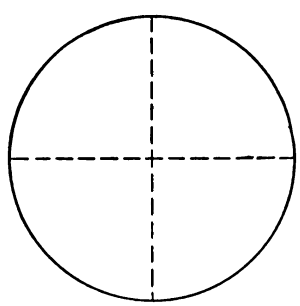
100% grid modulation. The ideal 100% grid modulation pattern for system without inverse feedback. Note slight curvature of sides.



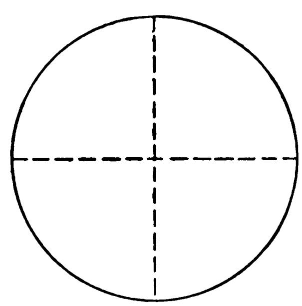
Sketch Note



Sketch Note



Sketch Note



Sketch Note

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## MODULATION PATTERNS

(Wave Envelope Type)

Greater range of indication is possible with this type as compared to the trapezoidal form. However, for the average operator the correct interpretation is more difficult. There are fewer " typical condition " patterns available because special conditions usually produce wide pattern variation. Speech amplifier adjustment, audio distortion, etc., are best checked separately after the methods of the sine-wave testing and square-wave testing sections. The wave envelope check is best reserved for the final combination of the audio and radio frequencies, after it is reasonably certain that the input to the modulator is of satisfactory form. The Class B load match (modulation transformer load adjustment) can be checked with the audio wave across the modulator load.

**I. Conditions.** A portion of the modulated signal voltage applied to the vertical plates. Linear sweep applied to the horizontal plates. Ratio between audio and linear sweep 2 : 1 (2 cycles appear upon the screen).

*a.* Percentage modulation is equal to $\frac{\text{increased height}}{\text{unmodulated height}} \times 100$

In Figs. 93, 94, 95, percentage modulation is equal to $\frac{h^2 - h^1}{h^1} \times 100$, where $h^1$ equals height of unmodulated carrier and $h^2$ equals height, in same units, of modulated carrier.

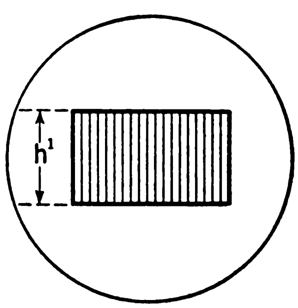


FIG. 93

**Carrier unmodulated.**

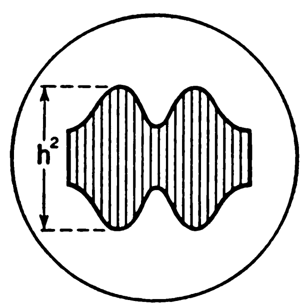


FIG. 94

**Approximately 50% modulated.**

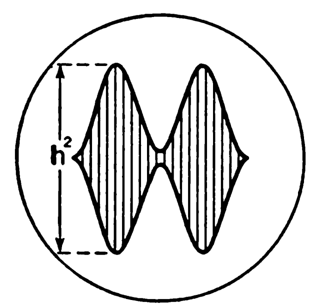


FIG. 95

**100% modulated.**

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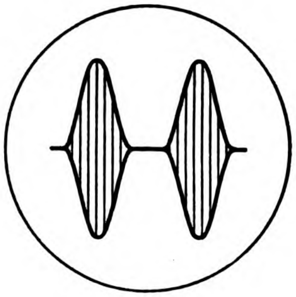


FIG. 96

Overmodulated (more than 100%). Note separation between cycles and thin, bright, connecting line.

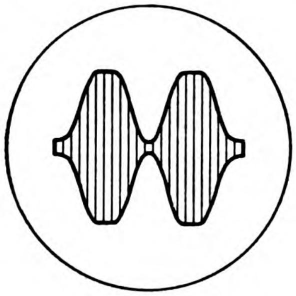


FIG. 97

Insufficient grid drive to final modulated amplifier. Note clipping of peaks.

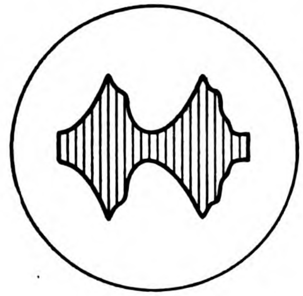


FIG. 98

Plate circuit of modulated amplifier detuned from resonance. Pattern shows phase modulation. (Neutralized triode amplifier.)

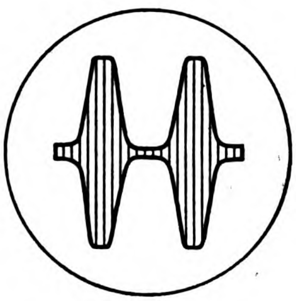


FIG. 99

Heavy overmodulation with considerable audio distortion. Compare with Fig. 96.

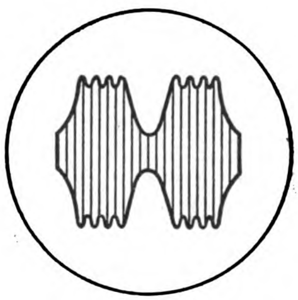


FIG. 100

Same as Fig. 97 but also mismatch in load between Class B and Class C, with "final" oscillating at spurious frequency.

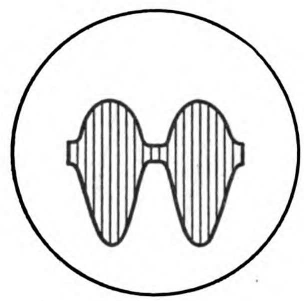
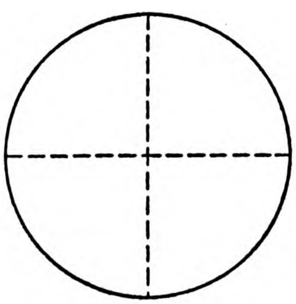
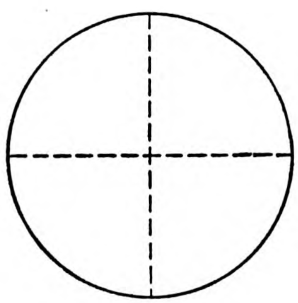


FIG. 101

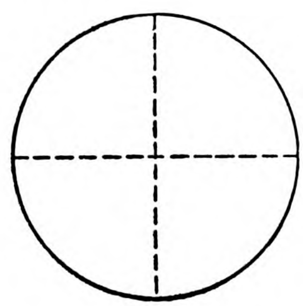
Rectification or overload in oscilloscope amplifier itself. Reverse of this pattern would indicate detuned "final" in grid-modulated Class C.



**Sketch Note**



**Sketch Note**



**Sketch Note**

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## SINE-WAVE TESTING

Many effective tests are possible in this simple system, in which an undistorted sine wave is fed through the circuit under investigation and thence to the vertical plates of the 'scope. The amount of distortion, attenuation, etc., appearing on the screen is a measure of the faults in the circuit under investigation.

For simplicity, the series of typical patterns herewith illustrate various conditions in connection with tests on a single-stage Class A, resistance-coupled pentode amplifier. The amplifier under test will be designated merely as " amplifier."

**I. Conditions.** As a first step, the operator should determine whether the amplifier power supply itself is introducing any distortion. A full wave, condenser-choke type power supply is assumed. Sine wave is applied through the amplifier to the vertical plates, and linear sweep to the horizontal plates.

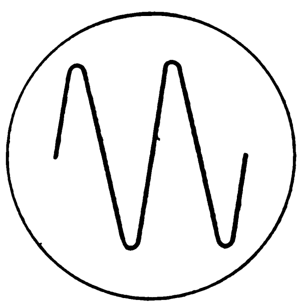

FIG. 102

360 c/s sine wave. No distortion.

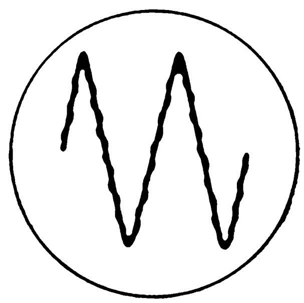

FIG. 103

One filter condenser removed from amplifier power supply. Heavier, fuzzy lines with thickness at top.

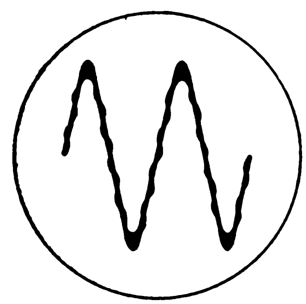

FIG. 104

Choke removed from amplifier power supply. About the same as Fig. 103, with addition of thickness at bottom.

*a.* Distortion (if any) due to pick-up in the amplifier itself from insufficient shielding should first be isolated and corrected. Figures 105, 106, and 107 illustrate a special condition in which the amplifier is picking up 60 c/s and the oscillator and linear sweep are multiples and submultiples of 60 c/s. It is given because the general sine-wave outline of the pattern will be confusing unless the cause is understood. The number of multiple lines will depend upon the ratios used.

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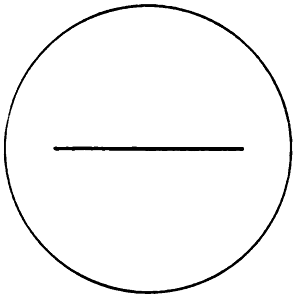

FIG. 105

Pattern due linear sweep alone, amplifier connected but no oscillator signal input. No pick-up.

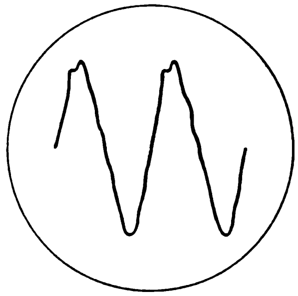

FIG. 106

Same as 105 but amplifier grid picking up 60 c/s and amplifying it. The linear sweep on 30 c/s. No oscillator signal input.

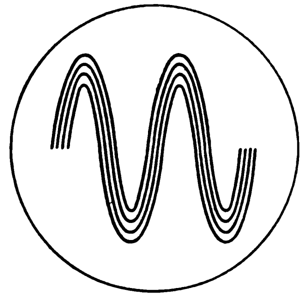

FIG. 107

Same as 106 but oscillator now delivering signal to input of amplifier which is still picking up 60 c/s.

**II. Conditions.** Where it is of value to know the polarity of the half cycles the reversing action of amplifiers must be remembered. And the amplifiers in the 'scope itself, of course, are no exceptions to the rule. To check the set-up of a particular 'scope, the operator can proceed with a battery (using a high-value resistor across it if direct connection to the plates is impossible) to the vertical plates and, by intermittent connection, determine the direction of movement of the dot, as illustrated in Figs. 108, 109, and 110. Figures 111, 112, and 113 illustrate this action (reversing) with an actual pattern.

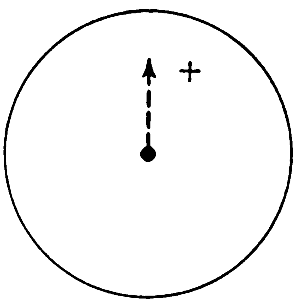


FIG. 108

No amplifier. Dot moves up.

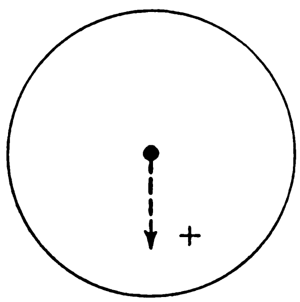


FIG. 109

One-stage amplifier. Dot moves down.

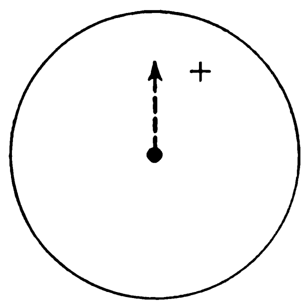


FIG. 110

Two-stage amplifier. Dot moves up.

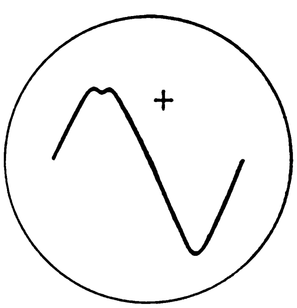


FIG. 111

No amplifier.

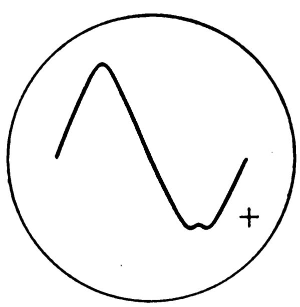


FIG. 112

One-stage amplifier.

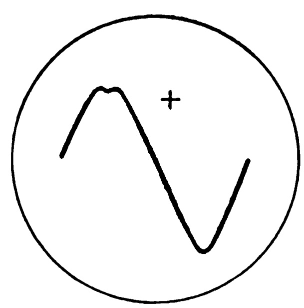


FIG. 113

Two-stage amplifier.

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**III. Conditions.** Undistorted sine wave fed through one-stage amplifier to vertical plates. Linear sweep to horizontal plates. Figure 114 to be taken as an approximate standard for attenuation.

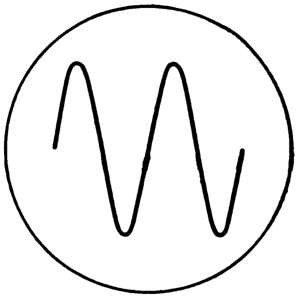


Fig. 114

Sine-wave input to amplifier. Undistorted.

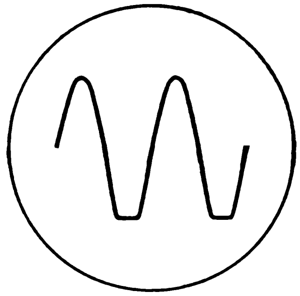


Fig. 115

Insufficient bias. Clipped peaks. Some attenuation.

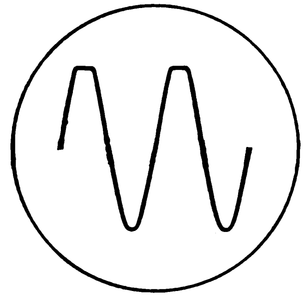


Fig. 116

Too much bias. Clipped peaks. Very little attenuation.

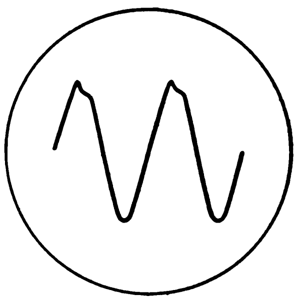


Fig. 117

Screen by-pass condenser too small. Distortion. Some attenuation.

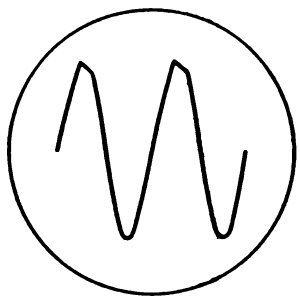


Fig. 118

Cathode by-pass condenser too small. Distortion (not passing all lows). Very little attenuation.

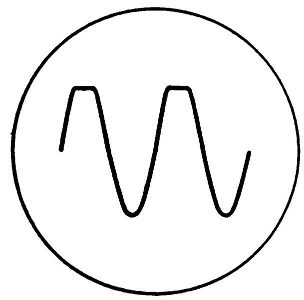


Fig. 119

Screen resistor much too high. Badly clipped peaks and considerable attenuation.

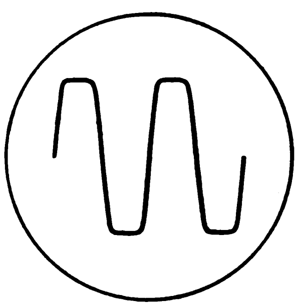
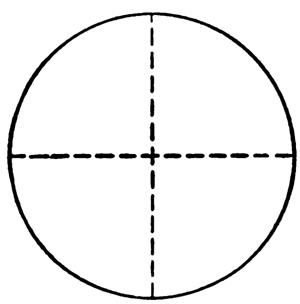
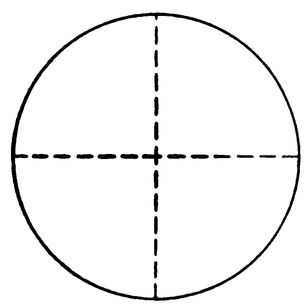


Fig. 120

Heavy overload, excessive bias, or both. Pattern begins to approach square wave.



Sketch Note



Sketch Note

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## SQUARE-WAVE TESTING

Square-wave testing makes it possible to determine the transient response of a system. Phase, frequency, and amplitude characteristics are all indicated. For audio fidelity it is thought that phase distortion is not of importance because it is not detected by the ear. With the increasing use of higher frequency amplifiers, however, the matter becomes of significance. The operator should bear in mind that the true square wave contains only the odd harmonics. Thus if the input to the square-wave generator has a frequency of 1,000 c/s, the *lowest* harmonic in the square-wave output will be 3,000 c/s, and this must be taken as the basis for calculating the frequency response of the system under test. When phase shift is directly proportional to frequency, the system is said to possess constant delay.

A reasonably useful square wave can be generated by overexciting a heavily biased conventional Class A amplifier. This type of voltage wave is also produced across the plate resistors of several types of triggered multivibrators, and by simple diode limiter circuits. More complicated circuits are necessary to generate a square wave approaching the ideal form.

**I. Conditions.** Oscillator, with frequency control, delivering sine wave of good form to a square-wave generator, which in turn is fed to the vertical plates through the system under investigation. Linear sweep applied to horizontal plates.

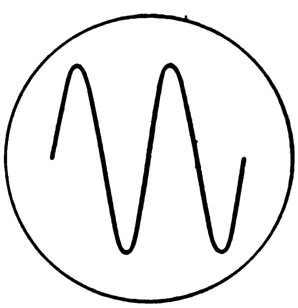

FIG. 121

Input to square-wave generator.

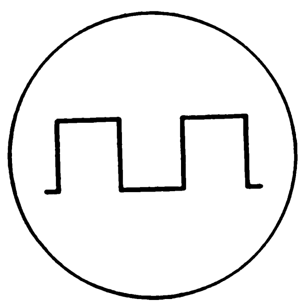

FIG. 122

Ideal square waves. Equal delay. Constant gain at all frequencies.

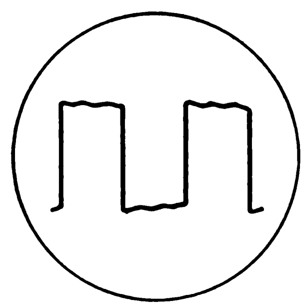

FIG. 123

Typical square-wave output of overloaded Class A amplifier.

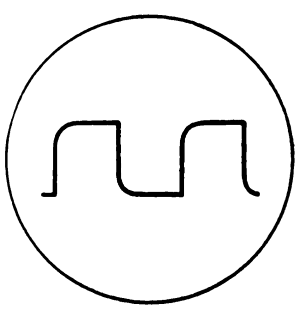

FIG. 124

Opposite corners are rounded. Delay unequal in system under test.

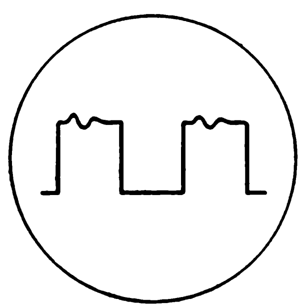

FIG. 125

Oscillations appear on only one side of wave. System under test, cut-off, or saturated.

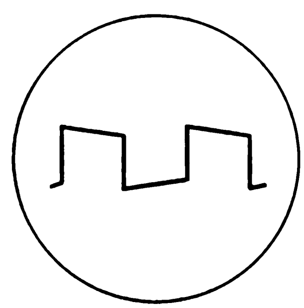

FIG. 126

Slant (in either direction) indicates phase shift in system under test at frequency being used.

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**II. Conditions.** Same as I. Low-frequency response patterns. Attenuation of low-frequency response is usually the effect of interstage coupling and coupling capacitors between plate and grid and successive stages.

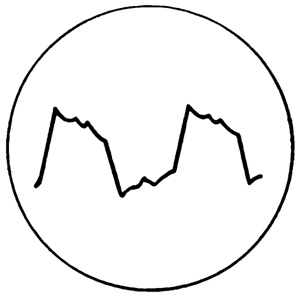

FIG. 127
60 c/s
Poor low-frequency response. Distortion, attenuation, and phase shift.

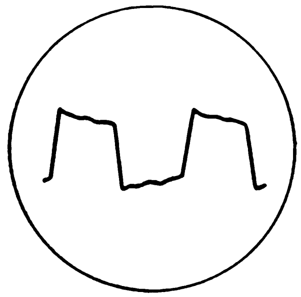

FIG. 128
60 c/s
Fair low-frequency response. Less distortion, attenuation, and phase shift.

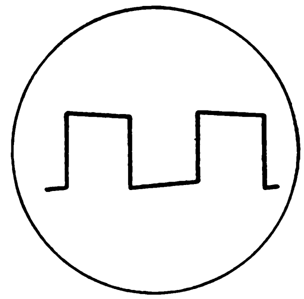

FIG. 129
60 c/s
Good low-frequency response. No attenuation. Very slight phase shift. No distortion.

**III. Conditions.** Same as I. High-frequency response patterns, on a typical amplifier with very poor high-frequency response. The trouble in this case was too high a plate load resistor, a common cause of poor high-frequency response.

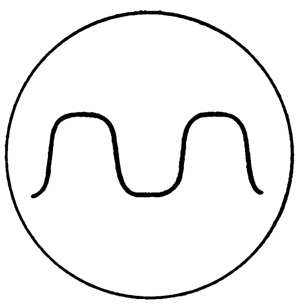

FIG. 130
150 c/s
Response falling off. Note rounded corners. Very little attenuation.

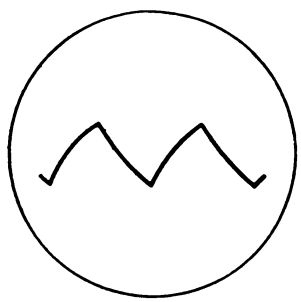

FIG. 131
500 c/s
Considerably more attenuation with some phase shift at high frequency.

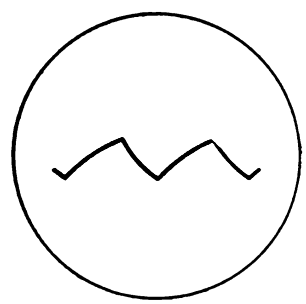

FIG. 132
2,000 c/s
Very high attenuation at high frequencies with marked phase shift.

*a.* If an amplifier exhibits a pattern which is essentially a sine wave at some frequency, $f$, it indicates that the system does not pass $3 \times f$ (the third) or any higher harmonic frequencies contained in the square wave.

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**IV. Conditions.** Same as I, but square wave is fed to the vertical plates through an audio transformer of the inexpensive type. Note that except for phase shift the response is fairly good at 300 cycles and that the pattern begins to round off at 1,800 cycles. Thus for voice frequencies between 300 and 5,400 cycles the response should be reasonably satisfactory. The transformer passes the first odd (third) harmonic of 1,800 c/s to some extent, because the general square wave shape is maintained in Fig. 135.

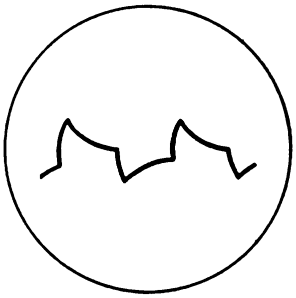


FIG. 133
Transformer at 60 c/s.

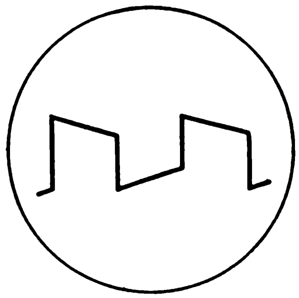


FIG. 134
Transformer at 300 c/s.

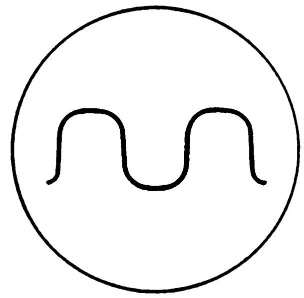


FIG. 135
Transformer at 1,800 c/s.

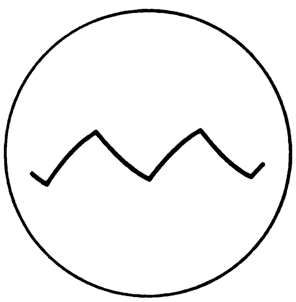
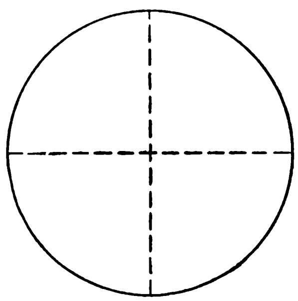
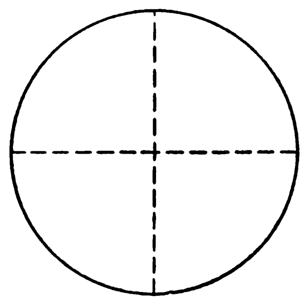


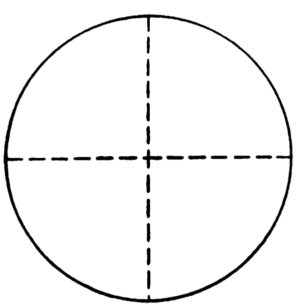
FIG. 136
Transformer at 2,500 c/s.



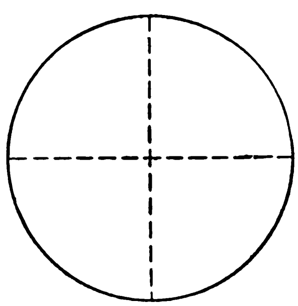
Sketch Note



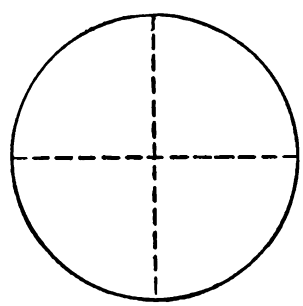
Sketch Note



Sketch Note



Sketch Note



Sketch Note

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## RESONANCE CURVES

With the proper equipment it is possible to align tuned circuits visually on the 'scope. The curves produced are known as resonance curves. In addition to the 'scope and the tuned circuit under test, it is necessary to have a frequency-modulated oscillator, sometimes known as a " wobbulator." By any of a number of means, the oscillator is frequency modulated to produce a sweep either side of its generated frequency, usually plus and minus 10 to 15 kc. It is apparent that, if the oscillator frequency is set at the resonant frequency of the tuned circuit and the sweep on the 'scope coincides with the f-m sweep rate, the signal will sweep through resonance first in one direction and then in another. Two curves will be produced, each peaking at resonance and falling off of either side. Figures are given for explanation only. In actual alignment work the two are timed to coincide.

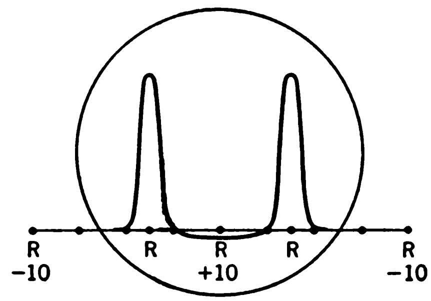


Fig. 137
Pair basic curves. Symmetrical type.

Linear 'scope sweep same timing as f-m sweep produces two curves, one for each travel through resonance. Figure 138 would be reversed if sweep timed to start at other end.

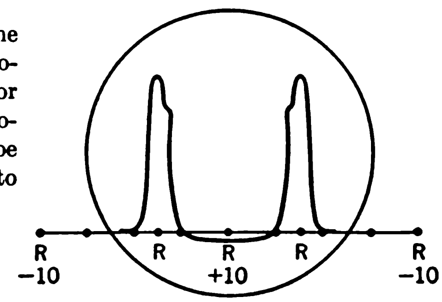


Fig. 138
Pair basic curves. Asymmetrical type.

*Note.* The vertical lines across the figures and calibrations on them in this section refer to an especially calibrated transparent scale to fit over the face of the CR tube. These calibrations should, of course, correspond to the sweep width of the f-m oscillator used.

**I. Conditions.** Vertical deflection produced from rectified f-m signal voltage. Horizontal deflection produced from synchronized linear sweep with this sweep set at *twice* the frequency of the f-m sweep. For hook-up circuits and other details too lengthy to be given here, the operator should consult the Reading List on page 39 and the descriptive literature of manufacturers of test equipment.

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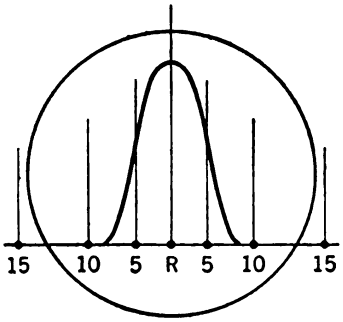


Fig. 139

Typical good response for average receiver. Note symmetry either side resonance, marked *R*.

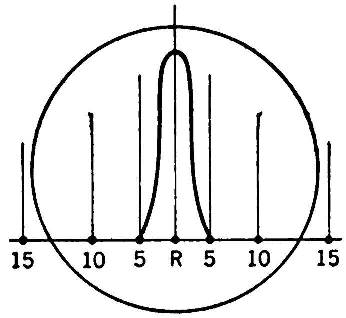


Fig. 140

Typical good response for narrow band receiver of the communications type.

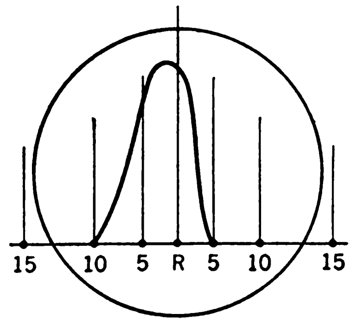


Fig. 141

Misaligned band pass, stage cut off on one side. Not symmetrical either side *R*.

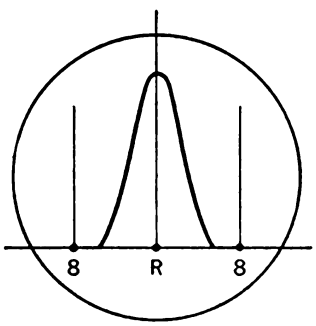


Fig. 142

Band pass. Coupling too loose giving sharp peaked curve and insufficient band width.

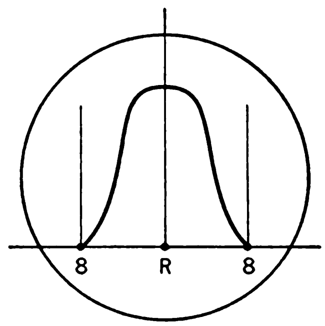


Fig. 143

Band pass. Coupling about right. Gives an approach to flat top and has band width.

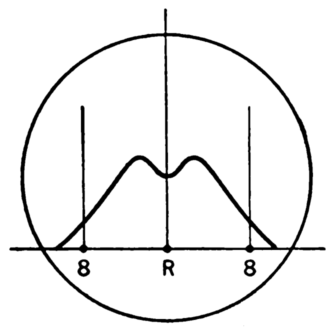


Fig. 144

Band pass. Coupling too tight. Too broad. Attenuated. Hump might also occur in Fig. 143.

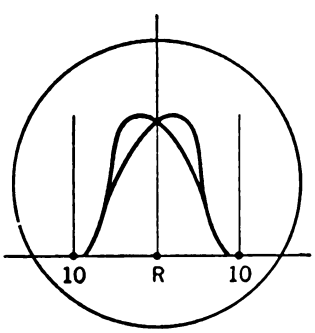


Fig. 145

Misaligned, wrong frequency. Bases coincide but peaks do not. A distorted form of non-coincidence is caused by regeneration.

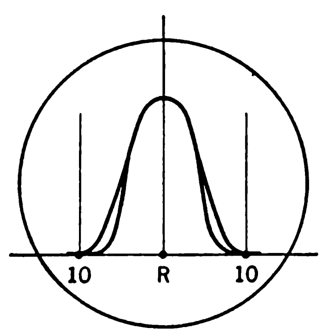


Fig. 146

Alignment correct for peaks but circuit does not respond properly over band. Somewhat similar pattern may result from excessive f-m voltage input.

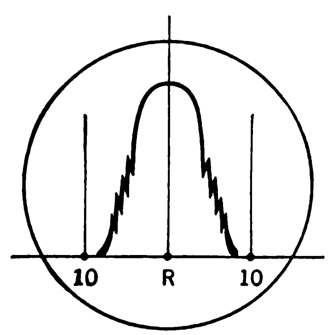


Fig. 147

Alignment correct but jagged sides and thickness at bottom indicate oscillations.

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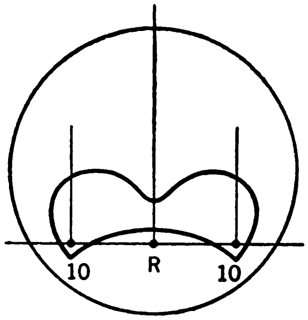



Fig. 148

I-f response across diode load resistor. Way off resonance. Broad, distorted.

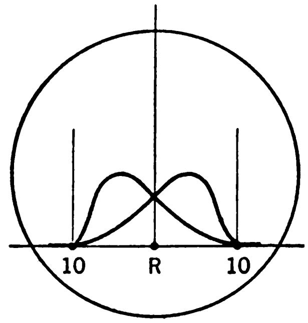



Fig. 149

Same i-f nearer to resonance, still broad but less distortion.

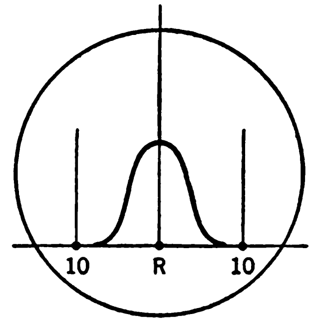



Fig. 150

I-f of Fig. 149 at best possible alignment. At resonance and fairly good i-f curve.

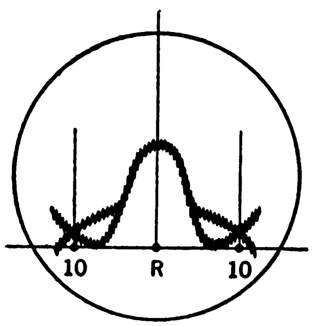



Fig. 151

Overall response receiver of Fig. 150. Tuned to resonance but phase distortion and oscillating amplifier in audio system.

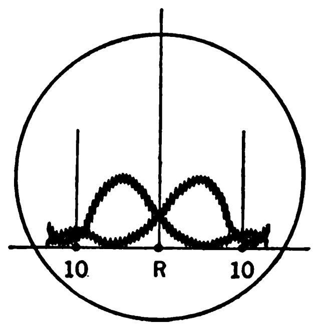
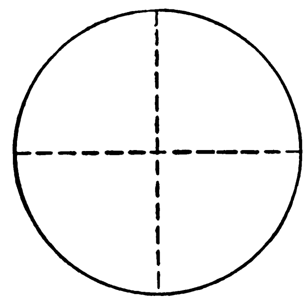
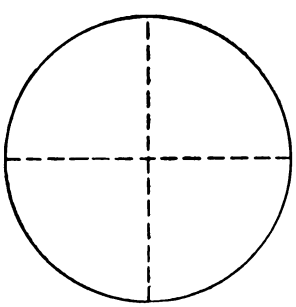



Fig. 152

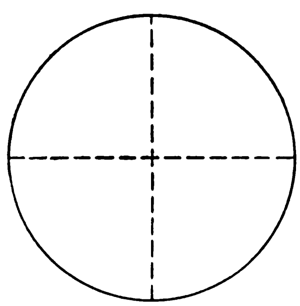
Same as Fig. 151 but not tuned to resonance. In these cases it was the oscillator which was detuned.



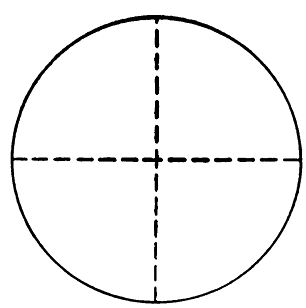
Sketch Note



Sketch Note



Sketch Note



Sketch Note

## VACUUM-TUBE CHARACTERISTICS

The 'scope offers a comparatively simple and very rapid method of plotting vacuum-tube characteristic curves for direct inspection. From the experimental curves, schematics, and brief notes, it is hoped the operator will find sufficient basic information to enable him to proceed with most routine tests.

For more detailed information and laboratory procedure the operator is referred to such articles as " Technique for Tube Data," by C. C. Street, in *Electronics* for October, 1941, and " Tracing Tube Characteristics on a CR Oscilloscope," by Jacob Millman and Sidney Moskowitz, in *Electronics* for March, 1941. The schematic for plate characteristics is a simplified version of that appearing in the C. C. Street article; the use of unfiltered rectified full wave alternating current is suggested by the Millman and Moskowitz article; the schematic for transfer characteristics is more or less standard and occurs in Rider, Von Ardenne, and other works, in the Reading list.

*a. Notes.* All curves for the section were produced one at a time on the 'scope and traced directly onto tracing paper. " Families," of course, could have been produced by successive photographs or a system of electronic or mechanical switching. Note that on some 'scopes certain sets of characteristics may be " backward " in slope as compared to the conventional manner of representation. The operator may reverse them in plotting if desired without altering their significance. Difference in setting of the amplifiers used will alter the general appearance (but not the basic proportionality) of the curves; thus the amplifiers should remain at a fixed setting for each series or " family." The resistor $R$ should be kept as small as practicable as it introduces an error in proportion to its comparative value. The lower limit is more or less determined by the degree of amplification without distortion or phase shift. Phase shift will cause an open-loop pattern instead of a line curve.

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**I. Conditions.** Triode (static) — plate voltage versus plate current — grid bias held constant at chosen values and plate current indicated as plate voltage is varied. Type 6C5 in circuit of Fig. 153. Curves will vary somewhat with individual tubes and value of resistor $R$ but should be reasonably typical, as compared with published static " families." Generator full wave rectified, but unfiltered voltage, set so it varies between zero and full d-c voltage. $E_f$ — filament voltage, $E_b$ — plate voltage, $E_c$ — grid bias voltage, $I_p$ — plate current.

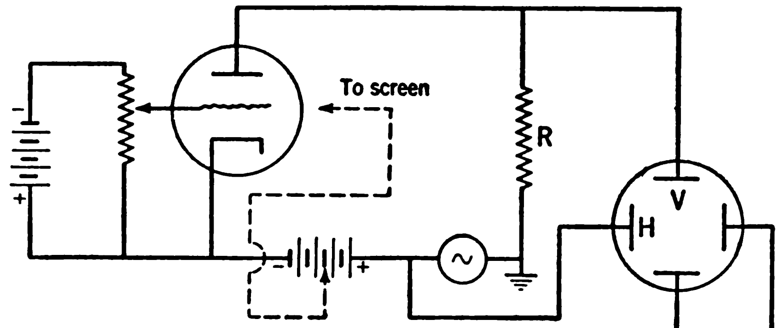


Fig. 153
Plate characteristics.

Figure 153 indicates hook-up for obtaining $E_b$ vs. $I_p$ (plate characteristics). Dotted line indicates method of connecting the screen grid for pentodes and tetrodes. Keep $R$ as small as practicable (500 ohms or less).

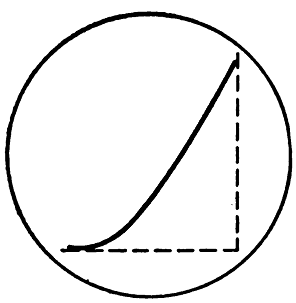

Fig. 154

Plate characteristics of 6C5 triode with $E_b$ equal to 157.5 volts and $E_c$ equal to $-3$ volts.

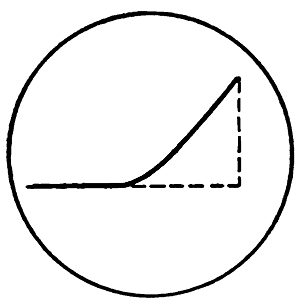

Fig. 155

Plate characteristics of 6C5 triode with $E_b$ equal to 202.5 volts and $E_c$ equal to $-6$ volts.

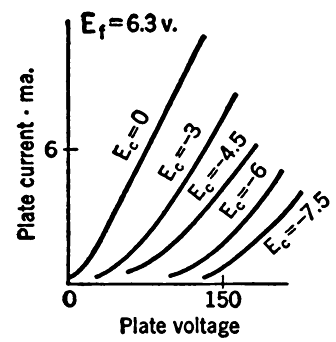


Fig. 156

Several plate characteristic curves of 6C5 combined into an experimental " family." Curves taken separately.

**II. Conditions.** Triode (static) — grid voltage versus plate current — plate voltage held constant at various chosen values and grid bias voltage varied. Type 6C5 in circuit of Fig. 157. General procedure same as I.

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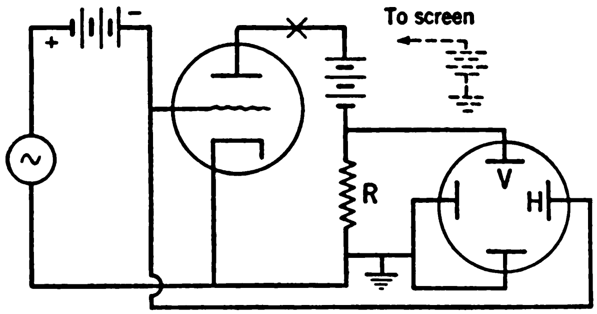


Figure 157 indicates hook-up for obtaining $E_c$ vs. $I_p$. For pentodes and tetrodes it simplifies matters to use a separate screen supply. $X$ indicates point where load resistor should be inserted for dynamic curves.

FIG. 157
Grid voltage vs. plate current.

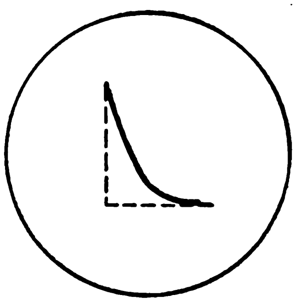

FIG. 158

$E_c$ vs. $I_p$ for 6C5 with $E_b$ at 90 volts and $E_c$ at −10.5 volts.

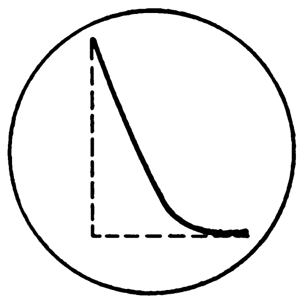

FIG. 159

$E_c$ vs. $I_p$ for 6C5 with $E_b$ at 135 volts and $E_c$ at −16.5 volts.

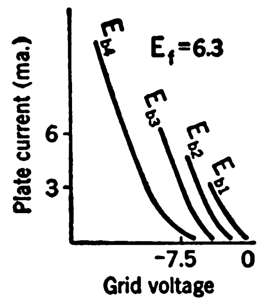


FIG. 160

Several grid voltage-plate current curves for the 6C5 combined into an experimental "family."

**III. Conditions.** Triode (dynamic) — grid voltage — plate current characteristics under load conditions. Some experimental (unrelated) load curves are given below. If a "family" is desired, one method is to choose a typical plate voltage and, holding it constant at the supply terminals for each step of varying grid bias voltage, plot the dynamic grid voltage-plate current curves for various values of load resistor ($R_L$), which is inserted at point $X$ in Fig. 157.

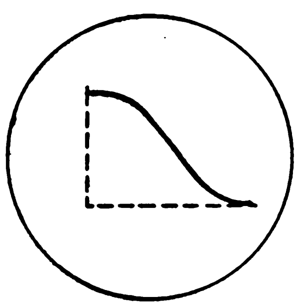

FIG. 161

Dynamic $E_c$ vs. $I_p$ for 6C5 with $R_L$ at 50,000 ohms, $E_b$ at 67.5 volts, $E_c$ at −7.5 volts.

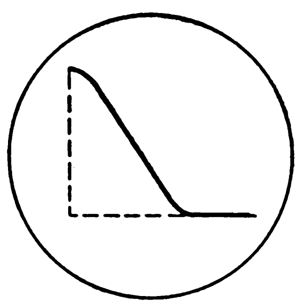

FIG. 162

Same as Fig. 161, with $R_L$ at 5,000 ohms, $E_b$ at 135 volts, $E_c$ at −22.5 volts.

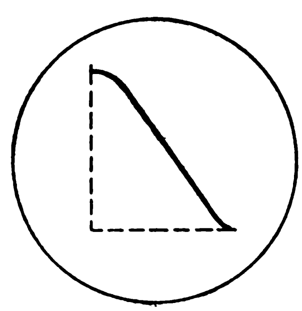

FIG. 163

Same as Fig. 161, with $R_L$ at 50,000 ohms, $E_b$ at 225 volts, and $E_c$ at −10.5 volts.

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**IV. Conditions.** Pentode (static) — plate characteristics. Same general procedure as I. Type 6J7 pentode in circuit of Fig. 153, screen connections as indicated by dotted lines. $E_{sc}$ — screen grid voltage. With full wave rectified, unfiltered input, pentode plate current wave form is partially square wave in shape. Two experimental curves are given. With more curves, " families " can be plotted.

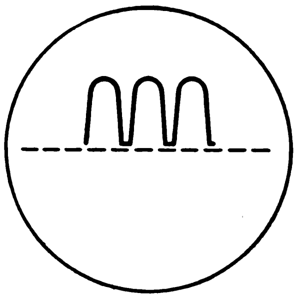


Fig. 164

Wave form plate current 6J7 pentode (input rectified but unfiltered full wave).

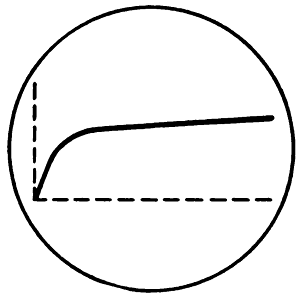


Fig. 165

Plate characteristics 6J7 as pentode. $E_{sc}$ at 67.5 volts, $E_b$ at 135 volts, $E_c$ at $-1.5$ volts.

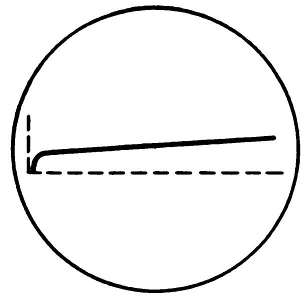


Fig. 166

Plate characteristics 6J7 as pentode. $E_{sc}$ at 67.5 volts, $E_b$ at 180 volts, $E_c$ at $-3$ volts.

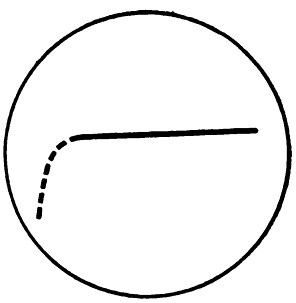


Fig. 167

(Pentode) generator voltage too low (in proportion). Dotted section not traced.

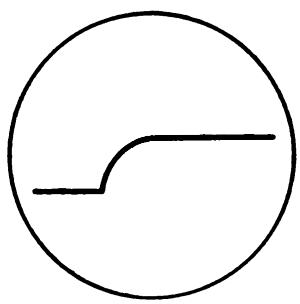
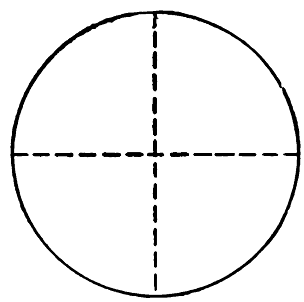


Fig. 168

(Pentode) generator voltage too high. Note " tail."



Sketch Note

**V. Conditions.** Type 6J7 as tetrode (suppressor tied to plate). Plate characteristics. Same general procedure as IV. Secondary emission causes the " hump " in wave form of plate current and " dip " in plate characteristic curves.

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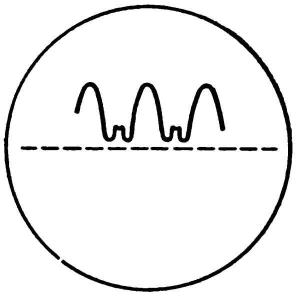


FIG. 169

6J7 as tetrode. Wave form of plate current. " Hump " indicates secondary emission.

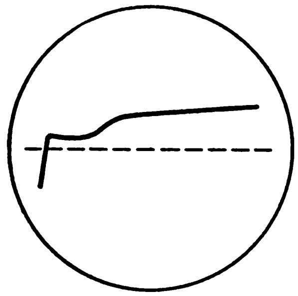


FIG. 170

Plate characteristics of 6J7 as tetrode. $E_{sc}$ at 67.5 volts, $E_b$ at 135 volts, and $E_c$ at $-1.5$ volts.

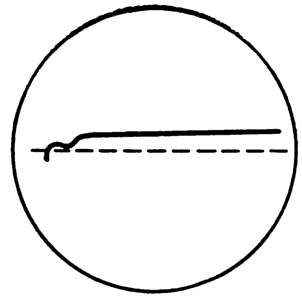


FIG. 171

Plate characteristics of 6J7 as tetrode with $E_{sc}$ at 67.5 volts, $E_b$ at 180 volts, and $E_c$ at $-3$ volts.

**VI. Conditions.** Pentode (static) — grid voltage — plate current characteristics. Because, in a pentode, plate voltage has little effect on plate current for values of plate voltage above a constant screen voltage, a single curve usually yields sufficient information for most purposes. 6J7 pentode in the circuit of Fig. 157, modified as indicated. The generator in this case was a variable output audio oscillator.

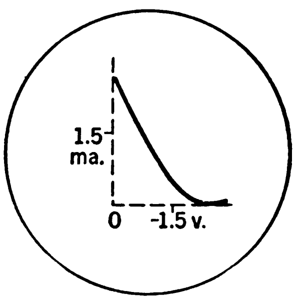
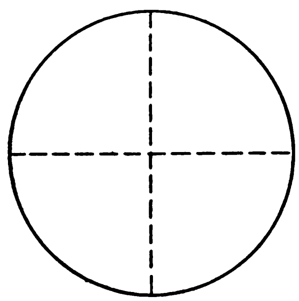
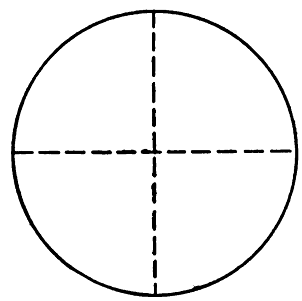



FIG. 172

$E_c$ vs. $I_p$ for 6J7 as pentode with $E_b$ at 135 volts, $E_{sc}$ at 90 volts, and $E_c$ at $-3$ volts.



Sketch Note



Sketch Note

*a. Notes.* In order to emphasize certain features most of the values chosen throughout this section are experimental rather than typical.

*b. Notes.* " Constant current " curves, screen voltage vs. plate current for various values of grid bias, and pentode load (dynamic) characteristics can also be traced on the 'scope by some slight modifications of the foregoing material.

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## MISCELLANEOUS PATTERNS

**I. Conditions.** Special, see captions under sketches.

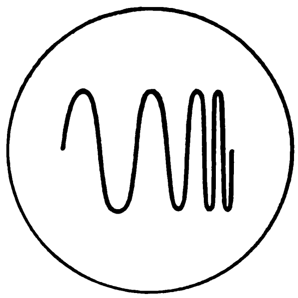


FIG. 173

Non-linear sweep. Note crowding at end. Bias too high on grid of sweep oscillator tube, or too low on current limiter pentode.

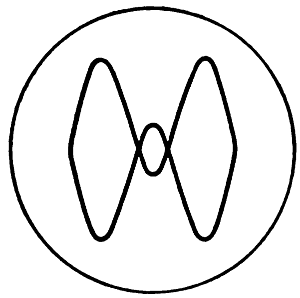


FIG. 174

A variation of Fig. 107, when ratio of linear sweep to pick-up is 9 : 2 (one of a great number of possible variations).

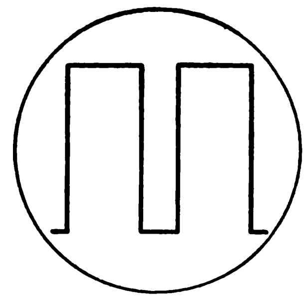
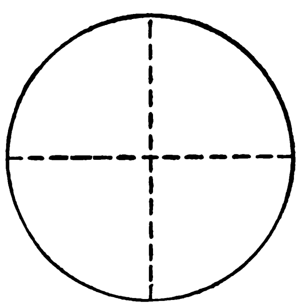
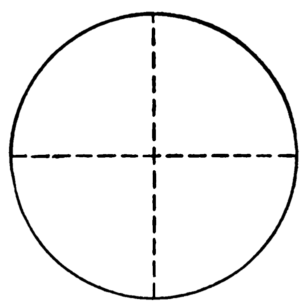


FIG. 175

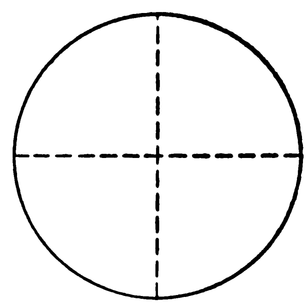
This general type with unequal time intervals contains the even as well as the odd harmonics.



Sketch Note



Sketch Note



Sketch Note

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## GRAPHIC ANALYSIS

For the operator with no previous knowledge of the subject, a description of simple graphic analysis as applied to cathode ray patterns may be of interest. No knowledge of mathematics is involved; in fact, this type of analysis is amazingly simple, once the system is understood. The accuracy of the resultant will depend largely upon the scale used, and the care with which the vertical and horizontal components are drawn, and points plotted.

It might be noted at this point that the phase angles represented in Graph 1 and Graph 2 are reversed in tilt from the patterns developed for the earlier sections of this guide. For explanation, see phase determination, Fig. 4 and Fig. 5.

To set up a problem it is necessary to know the characteristics of the two wave forms whose resultant is to be plotted, the amplitude, the frequency, and the phase difference.

In Graph 1 the two forms are essentially sine wave, the amplitude (the distance $AB$) is the same, the frequency (number of complete cycles in distance $BC$) is the same, the phase difference (point in time on the zero axis from which plotting is commenced) is the same, i.e., difference equal to zero. Other distances in time could be taken; for example, halfway between 1 and 2 or two thirds of the way between 8 and 9 on the vertical figure. But a corresponding point must be taken on the horizontal figure an equal distance in time from its point 1. Direction and method of plotting should be apparent from the graph.

In Graph 2 it will be noted that point 1 for the vertical figure, which is also the point of intersection with the figure, lies on the zero axis, but that on the horizontal figure point 1 is taken so that its intersection comes at a position representing 45 degrees. It is apparent, then, that the plotting for the two figures is started with a phase difference of 45 degrees.

In Graph 3 plotting is commenced with a phase difference of 90 degrees. Also note that, while the distance in time occupied by the two figures is exactly the same, there are two complete cycles in the horizontal figure and only one in the vertical figure. Therefore the frequency of the horizontal figure is correctly represented as twice that of the vertical.

A little study of the graphs should furnish any additional information necessary to enable the operator to utilize this interesting and valuable form of analysis.

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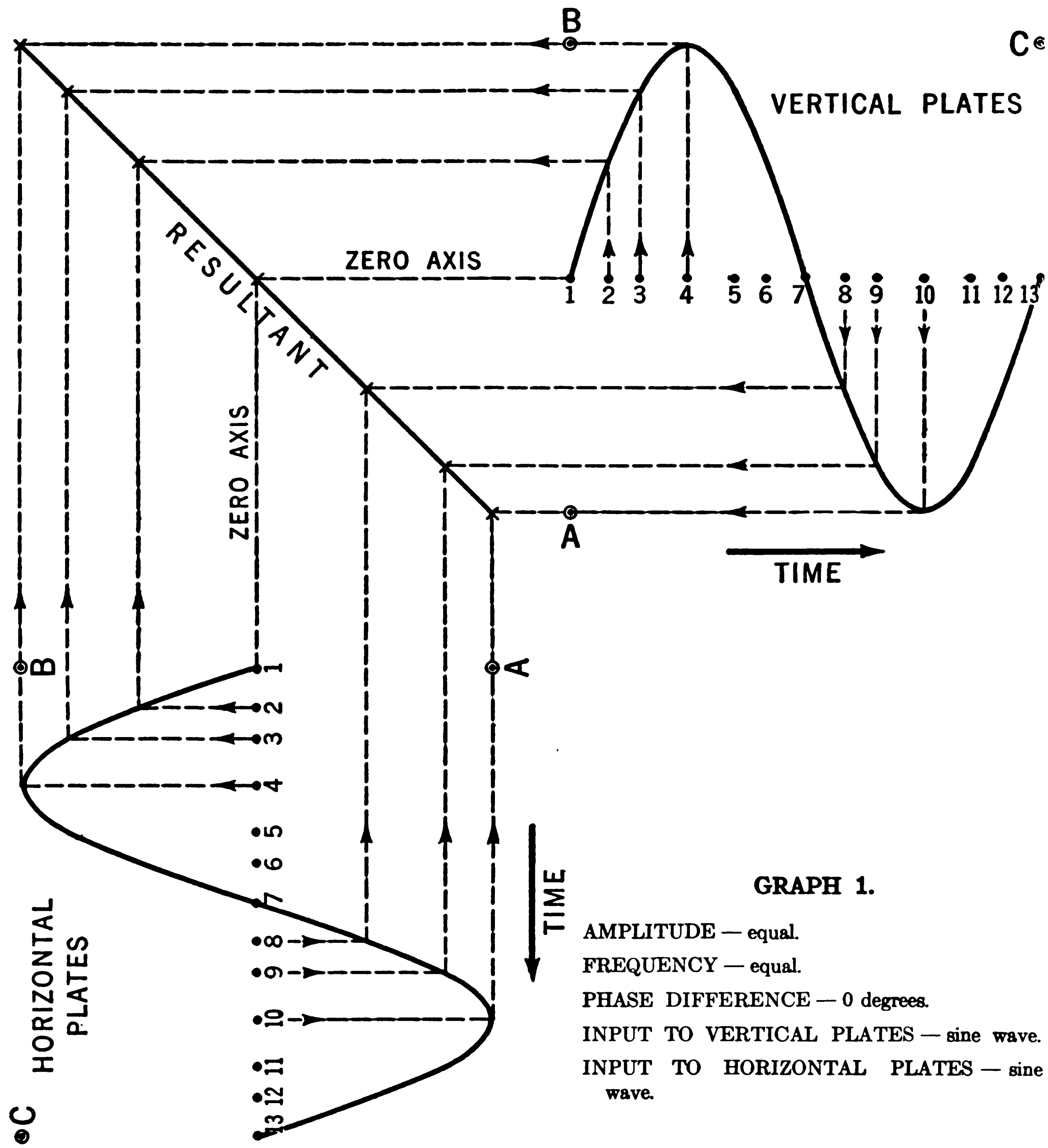


**GRAPH 1.**

AMPLITUDE — equal.
FREQUENCY — equal.
PHASE DIFFERENCE — 0 degrees.
INPUT TO VERTICAL PLATES — sine wave.
INPUT TO HORIZONTAL PLATES — sine wave.

*Amplitude* is represented by unit distance $AB$. *Frequency* is represented by the number of complete cycles in unit distance $BC$. *Phase* is represented by: point 1 as 0 degrees; point 4 as 90 degrees; point 7 as 180 degrees; point 10 as 270 degrees; point 13 as 360 degrees.

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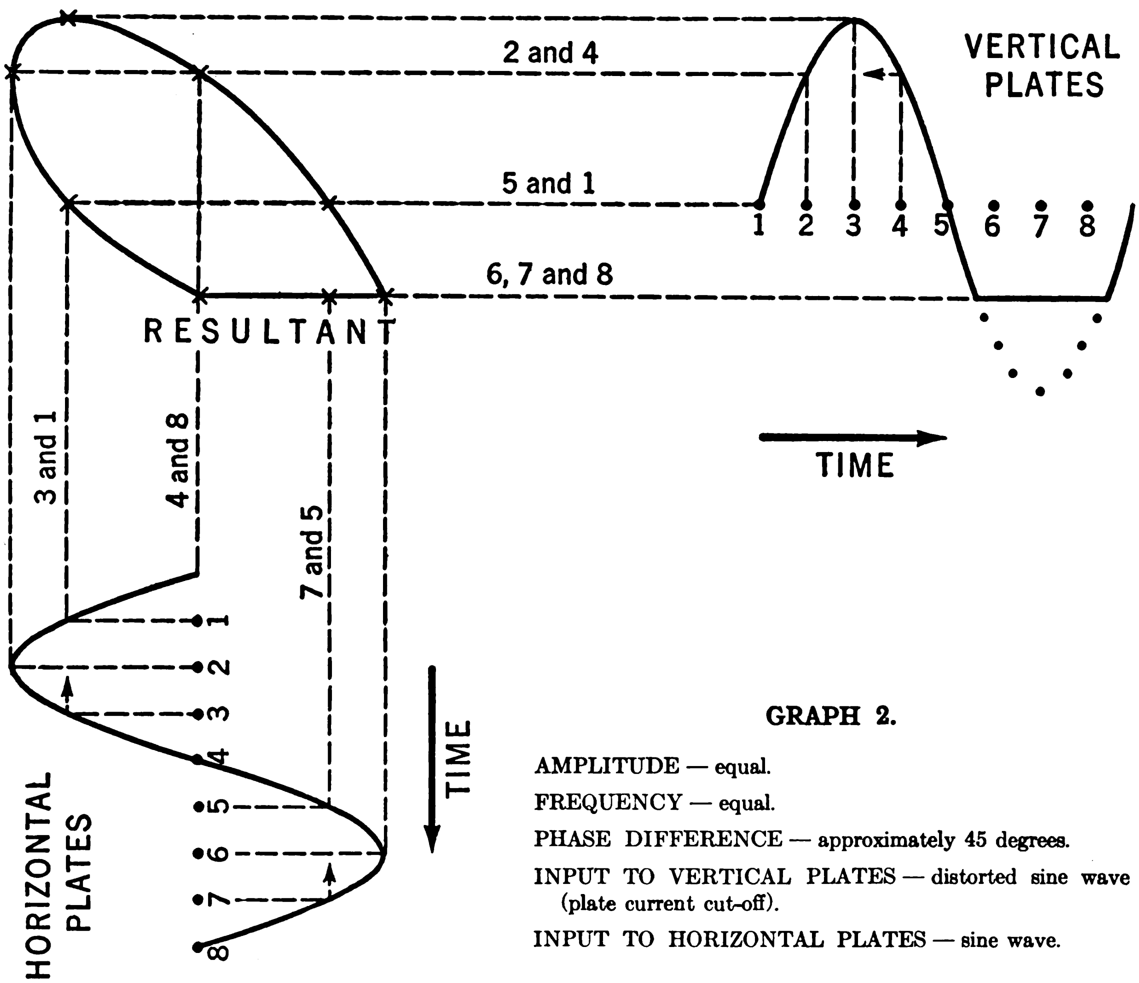


**GRAPH 2.**

AMPLITUDE — equal.

FREQUENCY — equal.

PHASE DIFFERENCE — approximately 45 degrees.

INPUT TO VERTICAL PLATES — distorted sine wave (plate current cut-off).

INPUT TO HORIZONTAL PLATES — sine wave.

Unless the operator can visualize the *resultant* somewhat in advance, it will be necessary to establish more points to plot it. They are omitted here to simplify the treatment.

Provided *time* is observed, both figures may be extended equally in either direction in order to obtain more points when desired.

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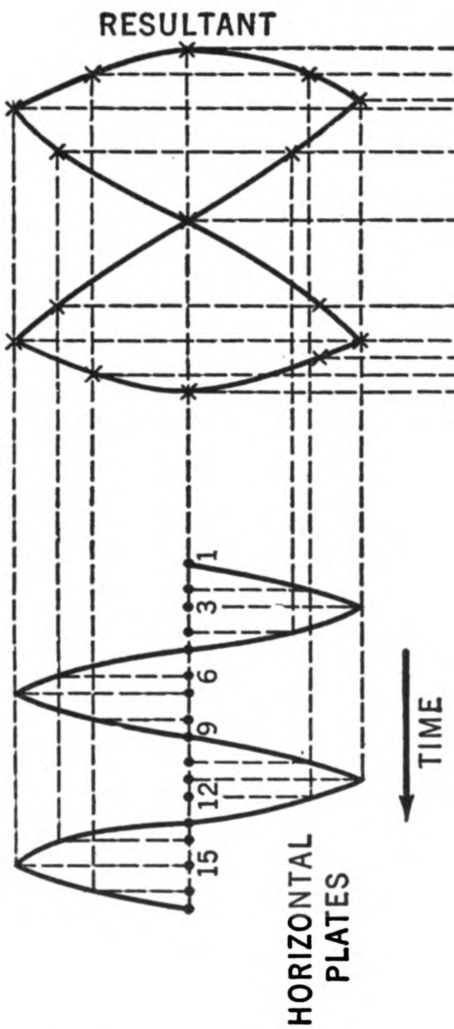


**GRAPH 3.**

AMPLITUDE — equal; frequency 2 : 1.

PHASE DIFFERENCE — approximately 90 degrees.

INPUT TO VERTICAL PLATES — somewhat distorted sine wave.

**INPUT TO HORIZONTAL PLATES — somewhat distorted sine wave.**

**Note that if pure sine waves had been used, the *resultant* would have exhibited a less angular appearance. Also note that it was necessary to extend the vertical pattern (dotted lines) to complete the *resultant* at all.**

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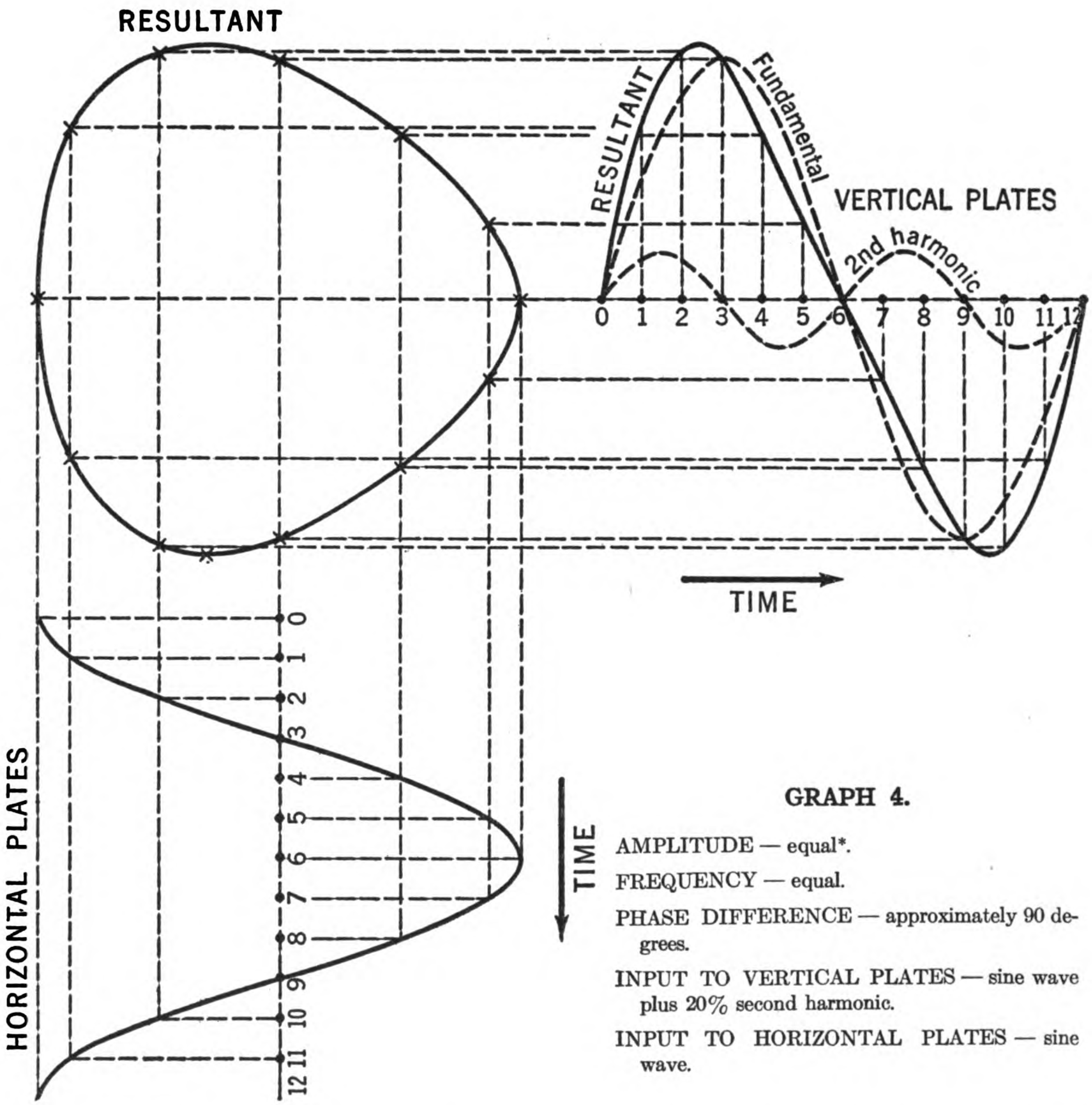


**GRAPH 4.**

AMPLITUDE — equal*.

FREQUENCY — equal.

PHASE DIFFERENCE — approximately 90 degrees.

INPUT TO VERTICAL PLATES — sine wave plus 20% second harmonic.

INPUT TO HORIZONTAL PLATES — sine wave.

**The second harmonic is, of course, twice the frequency of the fundamental, and the operator will note that it is plotted on that basis.**

**The phase difference indicated at the bottom of the graph is the phase difference between the fundamentals.**

**(*Note that the second harmonic has been added algebraically to the fundamental.)**

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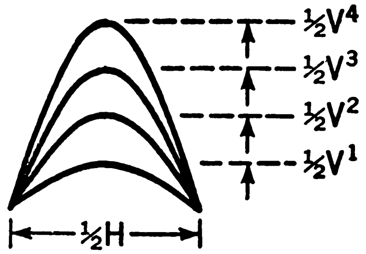


Fig. A

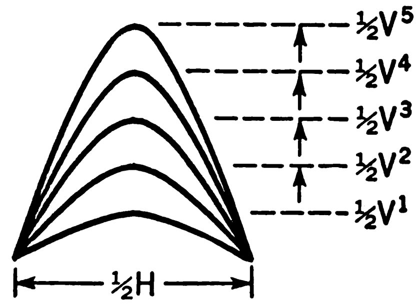


Fig. B

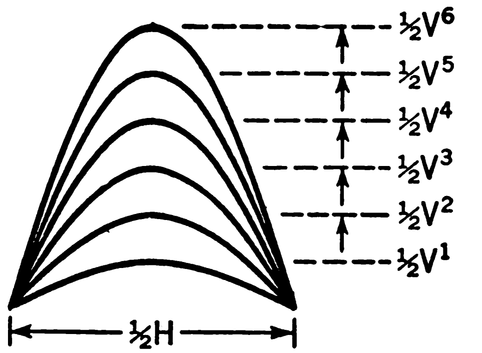


Fig. C

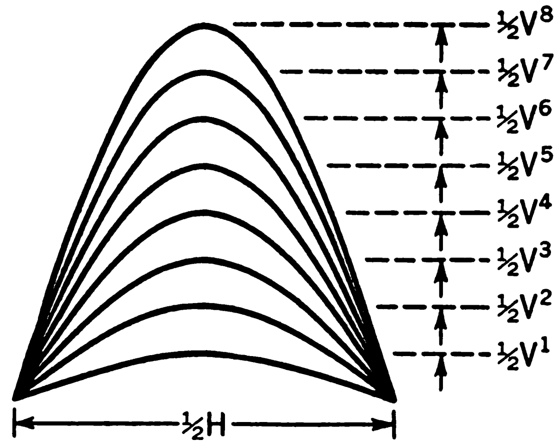


Fig. D

## " PERFECT " HALF-SINE WAVES

Figures *A*, *B*, *C*, and *D* are " perfect " half-sine waves of various amplitudes. The eye is not capable of judging accurately whether a wave form is perfectly sinusoidal without some reference standard. It can be understood that it is often desirable when viewing a particular sine-type pattern to know just how it deviates from the " perfect " form.

*Directions.* Take a piece of tracing, or other thin paper, and, after choosing the curve from any one of the four figures that appears to match most nearly the one to be checked on the 'scope, trace the selected half-sine wave. Now turn the paper around and trace it again, thus completing the full sine wave on your tracing paper. Lay the tracing against the front of the CR tube, adjust the horizontal gain on the 'scope to coincide with the distance *H* of the traced figure, and the vertical gain to coincide with the distance *V* of the traced figure, as nearly as possible. The divergence between the superimposed tracing and the figure on the CR tube will give a general indication of the type and amount of deviation from the " perfect " sine-wave form.

*Note:* Distances *H* and *V* above refer to the horizontal and vertical amplitude of the *whole* sine wave, and are therefore twice the actual drawn dimensions of any curve in the figures.

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## READING LIST

In addition to the numerous excellent technical magazines available, the following books are suggested as containing material of interest on cathode ray patterns.

*The Cathode Ray Tube at Work*, J. F. Rider, published by the author, New York, 1935.

*Cathode Ray Tubes*, M. Von Ardenne, Sir Isaac Pitman & Sons, Ltd., London, 1939.

*Measurements in Radio Engineering*, F. E. Terman, McGraw-Hill Book Co., New York, 1935.

*High-Frequency Measurements*, August Hund, McGraw-Hill Book Co., New York, 1935.

*"Radio" Handbook*, Editors and Engineers (publishers), 8th Edition, 1941.

*Radio Amateur's Handbook*, 19th Edition, American Radio Relay League, West Hartford, Connecticut, 1942.

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